JOURNAL OF THE A·I·E·E·

MARCH 1927

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

American Institute of Electrical Engineers

COMING MEETINGS

SUMMER CONVENTION, Detroit, Mich., June 20-24

PACIFIC COAST CONVENTION, Del Monte, Calif., September 13-16

REGIONAL MEETINGS

South West District No. 7, Kansas City, Mo., March 17-18.

Middle Eastern District No. 2, Bethlehem, Pa., April 21-23

North Eastern District No. 1, Pittsfield, Mass., May 25-27

MEETINGS OF OTHER SOCIETIES

Joint Meeting, New York Section A. I. E. E., New York Electrical Society and National Research Council, March 23.

The American Physical Society, Washington, April 22-23.

National Electric Light Association
Southeastern Division, New Orleans, La., April 26-29
Nebraska Section, Grand Island, Neb., April 27-28
Middle West Division, Topeka, Kans., May 18-20

American Electrochemical Society, Philadelphia, Pa., April 28-30

Canadian Electrical Association, Clifton Hotel, Niagara Falls, Ont., May 25-27

National Electric Light Association, Atlantic City, N. J., June 6-10

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OF THE

American Institute of Electrical Engineers

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Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines, $10.50 to Canada and $11.00 to all other Countries. Single copies $1.00.

Entered as matter of the second class at the Post Office, New York, N. Y., May 10, 1905, under the Act of Congress, March 3, 1879. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on August 3, 1918.

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLVI MARCH, 1927 Number 3

Electrical Standardization

The subject of procedure and policy in the formulation of industrial electrical standards was brought to the attention of the Winter Convention in a forceful address of President Chesney, which is printed elsewhere in this issue of the JOURNAL. Briefly stated, the question at issue is whether the Institute should continue as in the past 28 years to be the final authority on electrical standards in this country, or should renounce part of its responsibilities in this connection and permit the final authority for a large part of the work of standardization to fall into the hands of various groups of manufactures and trade organizations. President Chesney stated in discussing the subject that the time has come for the A. I. E. E. either to take decidedly more responsibility and put more vigor back of its system of procedure in establishing electrical standards, or it must step aside and give some other body an opportunity to continue the work in a vigorous way. The Institute cannot stand in the same position it is today for any great length of time, he believes, without doing injury to the electrical industry.

The present situation grew out of the fact that several years ago some of the electrical trade associations started, as part of their work, the formulation of some standards, primarily those not in any way covered by the A. I. E. E. They have continued and gradually increased that work until there has been an overlapping in the production of standards until we now have both Institute standards and standards of various trade associations.

Having acquired a position for themselves in the field of standardization, these associations feel that they should have an official part in the making of electrical standards; in other words, official representation on the committee which carries on this work.

On the other hand, the Institute through its Standards Committee has taken the initiative in the formulation of electrical standards in America and its work is recognized as authoritative throughout the world. Although not officially represented, the members of the trade associations as well as users of the apparatus come together in the Institute Standards Committee and Sub-committees and develop the required standards in a way which has been generally satisfactory to all the interested sections of the industry. The electrical standards so issued have been identified with the name of the Institute, and its name should be continued in connection with them.

It will be apparent that the contentions in this matter are not primarily in regard to the actual subject matter of the standards but are concerned chiefly with procedure and jurisdiction. In the convention discussion of President Chesney's address it was the practically unanimous opinion that the Institute's past work and prestige in the field of electrical Standards fairly entitled it to continue to act as the final authority on American electrical standards.

The tentative method of procedure outlined in President Chesney's address is designed to meet the situation. The outstanding feature of this plan is the proposed nomination of 50 per cent of the membership of the Committee by trade associations, such nominees to be A. I. E. E. members. This tentative plan of organization and procedure provides for broadening the field of the Institute's standardization work and offers ample opportunity for the cooperation of all interested organizations. It has been accepted in principle by the A. I. E. E. board of directors and it is hoped will avert the chaos which would result from the adoption of different standards for the same thing by several bodies.

Some Leaders of the A. I. E. E.

Farley Osgood, thirty-seventh president of the Institute (1924-25) and, for the past twenty years, an enthusiastic worker for *public service* in every sense of the word,—was born at Chelsea, Massachusetts on the 5th of April, 1874. His elementary study was at St. Mark's Preparatory School, Southboro, Mass., followed by a course at Massachusetts Institute of Technology.

Mr. Osgood's first work after graduation was with the engineering department of the American Bell Telephone Company of Boston in 1894. Here he remained for nearly three years, studying telephony in all its branches and varying phases, each undertaking of his typifying energy, enthusiasm, determination and earnestness.

For a year after this early training, he traveled as engineer for the New England Telephone and Telegraph Company, covering its whole territory in Maine, Massachusetts and New Hampshire, inspecting central offices and customers' equipment and, with a special crew at his command, ordering new installations and replacing old apparatus with more modern equipment where he deemed it advisable to do so. In 1898 Mr.

Osgood left the New England field to identify himself with the New York and New Jersey Telephone Company, where he was chief clerk in the operating department, special plant engineer, assistant to the vice-president and division manager. In 1904, however, he returned to New England to accept an appointment as chief engineer and general manager of the New Milford Power Company, located at New Milford, Connecticut. The company was then carrying on an extensive work of construction, which, under Mr. Osgood's leadership, was completed and the operating force organized with far-reaching results, as this hydroelectric system supplied lighting and commercial and electric railway power to the whole lower portion of the State of Connecticut through a 33,000-volt transmission line. The work occupied Mr. Osgood until the year 1908, when he again returned to New Jersey to take up his work as general superintendent of the Public Service Corporation, later known as the Public Service Electric Company, and today covering practically the whole state of New Jersey for lighting, commercial power and electric railway service. Of his work here, an eminent engineer and educator remarked, "Mr. Osgood's work in connection with the design and operation of power plants has been so well known that it seems unnecessary to go into detail—it has my most hearty approval." The late Doctor Steinmetz also commented upon Mr. Osgood's work in the field of electrical investigation—"Mr. Osgood has done considerable original work on the early development of the aluminum cell lightning arrester which is now (1911) considered the only reliable type of arrester. This work included investigation of surges and oscillations on transmission lines and high-power electric systems in general, and I consider him a very well qualified engineer."

Beside ultra activity in all of his own personal matters, Mr. Osgood has found time to enter materially into the committee work of the Institute and other representative bodies. His work with the National Joint Committee on Overhead and Underground Cable Line Construction as the Institute's representative is outstanding in its achievement, as are also the results in which he has been influential with the National Fire Protection Association as the Institute's representative on the Electrical Committee since 1914. Other Institute Committees on which he has served are: The Edison Medal Committee (since 1914); the Executive Committee (since 1915); the Finance Committee, 1915-16; Safety Codes Committee (since 1914); Committee on Coordination of Institute Activities; John Fritz Medal Board of Award; Committee on Education; the Joint Power Factor Committee; as Manager of the Institute 1911-1914; and member of the Board of Directors; Vice-President, 1914-1916. He has also served as the Institute's representative on the U. S. National Committee of the I. E. C. and the American Engineering Council and on the Charles A. Coffin Fellowship and Research Fund Committee. In 1924, Rensselaer Polytechnic Institute conferred upon him the Doctor's degree. Not the least among Mr. Osgood's contributions to the profession and of special profit to young engineers have been his inspiring addresses at meetings of Institute's Sections throughout the country, chiefly during his term as president of the Institute. It was in 1925 that Mr. Hart, Secretary-Treasurer of the Engineering Council of Utah wrote, soliciting an address from Mr. Osgood, saying "our engineers crave a message of encouragement, advice and instruction in duties and opportunity for the advancement of service in the profession." Nor has the force of these addresses been felt alone by the student faction of the country. C. H. Markham, president of the Illinois Central Railroad remarked with high commendation upon many points brought out by Mr. Osgood as Chairman on Railroad Electrification from the Executive's Standpoint at the special meeting held under the auspices of the A. I. E. E., May 1925, while Mr. Osgood was its president and participated in by many of the largest railroad interests of the country. He has also played no small part in the activities of the American Engineering Council. At the time of the world war, Mr. Osgood was among the first to file his personal classification sheet for further service, notwithstanding the fact that he was already an associate member of the Naval Consulting Board. And not the least of his admirable characteristics is his keen sense of humor. He, himself tells the story of having been driving with some engineer friends when their car was halted by one of the flashing traffic signals—the first they had seen in operation. It was at a point where its protective measures were most essential and there was a general exclamation of "isn't that fine!" followed by individual speculation as to just how it was actuated. One advanced one theory and another another, until finally, the chauffeur, unable to comprehend most of the technical conversation, but apparently anxious to avert a heated argument, explained, "Gentlemen, it is run by gas!" Even had the man been correct in his assumption, being a good electrical engineer, the utilization of gas, either metaphorical or real, would probably not have appealed to Mr. Osgood, who is a man of definite action and deeds.

Impressions of the A. I. E. E. Convention

There is good reason for the electrical industry to be proud of its engineers. It has realized that engineering developments very accurately measure industry progress. The institute has grown to be a body of 20,000, and the winter convention in New York last week brought more than 1400 engineers together to discuss engineering topics. It was a meeting which afforded an opportunity to survey developments in the art and to comprehend the policy elements related to industry progress.—*Electrical World.*

Electrical Standardization

Opening Address of President C. C. Chesney at A. I. E. E. Winter Convention, February 7, 1927

FOURTEEN years ago the Midwinter Convention devoted practically all of its meetings to the subject of Industrial Standards and standardization. Recent activities within the Institute, and the activities in our sister professional societies, as well as the activities of the various Trade Associations and the Department of Commerce on this subject, must be my particular excuse for transgressing on the time of your other speakers, although the subject of standardization covers one of the most, if not the most, important present-day activity of the Institute.

I will, however, be as brief as the subject will permit, confining myself mostly to one phase of the subject in which we are primarily interested, that is domestic "Electrical Standardization."

Electrical Standardization began as early as 1882 in Great Britain and by this Institute in this country more than 28 years ago by the appointment of its first Committee of Standardization, consisting of Professor Francis B. Crocker, Dr. Cary T. Hutchinson, Prof. A. E. Kennelly, Dr. J. W. Lieb, Dr. C. P. Steinmetz, Mr. L. B. Stillwell, and Prof. Elihu Thomson—all outstanding names in the electrical engineering fraternity. The first standards for electrical machinery generally followed by the American electrical industry were those prepared by this committee, and adopted by the Institute in June 1899.

In this country and in Great Britain the term "standardization" has grown to mean, in the minds of engineers not only a simplification in the number of types and sizes and the securing of interchangeability, but also the laying down of performance rules or codes for all types of apparatus, including measuring instruments, prime movers, generators, transformers and motors. Thus broadly the term "Standard" in addition to being a measure of quality of standards of comparison, means a common unified practise, method or dimension, which it is to the interest of industry and the community to adopt. Back of any policy of standardization is primarily the purpose to furnish the public a better article or to render it a better service at a lower cost. In the electrical industry, as well as in industry generally, pioneer conditions have passed in this country. We can no longer count solely on our boundless opportunities, but must depend upon the ever increasing efficiency of our industrial organizations. Engineers recognize, and it has been effectively demonstrated, that a better nation-wide utilization of our industrial resources and efforts will be the outcome of a wide and broad policy of standardization of our industrial products, all being for the ultimate purpose that a greater and greater number of people may enjoy those comforts and conveniences which modern industry has introduced into life; thus not only maintaining the present standards of living, but aiming to improve these standards of living for both factory workers and farmers by placing production on a more stable footing. The high standards of living now enjoyed by the American people are the results of steadily mounting per capita productivity. As I have said on several previous occasions, the art of industrial standardization has received a rare impetus from the automobile industry, particularly from Henry Ford—that great apostle of mass production. He has given the art of standardization a dramatic coloring and value by applying the test of commercial experience in production which few, if any, in modern industrial life other than this dynamic and distinguished automobile manufacturer could have done.

The American Institute of Electrical Engineers since the formation of its original committee, has through its Standards Committee taken the initiative in the formulation of all electrical standards of America, and its work is recognized as being authoritative throughout the entire world. Its procedure and its resulting standards during this period have been acceptable to the manufacturing and the consuming interests as well as to the general public. The industry has learned to value and to depend upon the A. I. E. E. standards in commercial transactions covering matters of interest to all sections of the electrical industry. It has made no attempt to dictate to industry but introduces standards on any particular line only when it is clear that all interested parties agree that the step is wise and desirable.

In the Institute Standards Committee, or in its subcommittees, the manufacturer and purchaser and the general interests come together and develop the required standards in a way which has been generally satisfactory to all the interested sections of the industry. The electrical standards so issued have been identified with the name of the Institute, and its name should be continued in connection with them, and in the interest of simplicity and order it would appear that no other name was actually necessary. It should be remembered that the Institute as an organization has no interest other than one of public service, which duty the Institute has performed throughout the entire period of 28 years at its own expense. The Institute, therefore, in connection with the voluntary formulation of electrical standards, has assumed obligations during the past quarter of a century to the electrical industry and to the

public which would make it now embarrassing, if not impossible, to discontinue the present practise or lessen its responsibilities until a more simple and direct method has been devised and demonstrated.

While the formation of the American Engineering Standards Committee in 1917 has contributed very materially to the promotion of standardization in other departments of engineering the work of the Institute in electrical standardization had at the time of the formation of the A. E. S. C. already acquired such general acceptance that the further step of being approved by the A. E. S. C. subsequent to adoption as Institute Standard has not had any important significance.

Standardization problems today are greater in number and more intricate in character on account of the more complex forces actuating our industrial life, and recently there has been a feeling among some of our members and by interests outside of the Institute that a change in organization and procedure for the proper and more rapid handling of standardization matters was needed. Trade associations have sought to obtain greater influence and more authority in the formation of electrical standards which had heretofore been formulated by the Institute. This has led to controversies between the Institute and these trade associations and jurisdictional disputes thus arising have naturally handicapped the work and progress has been delayed. It has been affirmed by the representatives of the Trade Associations that "the trade associations have already become the most important factor in the standardization movement and their importance is steadily increasing." It is also suggested by the same interests that the professional societies' standardization efforts should be confined to scientific fundamentals and to exceedingly important pioneer work. Naturally the suggestion that the Institute and other professional bodies, expressed in the language of another, "be relegated to the field of scientific fundamentals and to association with only government departments" does not set well with the many friends of the Institute who know the service it has rendered in this line.

Let us take as an example the subject of Voltage Standards to which tomorrow-forenoon's technical session is to be devoted. Nine papers, some by representatives of manufacturers and some by representatives of consumers will be presented and discussed at that time. This symposium on voltage standardization is typical of the traditional Institute policy. The resultant opinion as developed by tomorrow's discussion will be further considered in the Institute's technical committees and in its Standards Committee, and should in due course contribute to an Institute standard in the preparation of which the entire industry will have participated.

On Feb. 9, 1926 the Board authorized a brief statement of its policy for transmission to the members of the Standards Committee and to representatives of the Institute upon any Committees or on joint bodies, dealing with the formulation of Standards.

1. To continue to develop, publish and maintain in the name of the Institute electrical standards as it has done for the past 25 years.

2. That in doing this work the Institute will continue as it has in the past to avail itself to the fullest degree of the assistance of others—both individuals and organizations—with a view to serving the interests of all who may be properly concerned in this work.

3. That Standards after having been developed by the Institute in accordance with 1 and 2 and adopted by the Board of Directors as Institute Standards will be, when in the opinion of the Institute such a step is proper, presented to the American Engineering Standards Committee for approval by them as American Standards.

4. That such presentation to the American Engineering Standards Committee for their consideration for approval as American Standard will be done in full conformity with the Constitution, By-laws and Rules of Procedure of the American Engineering Standards Committee, which Committee the Institute was instrumental in initiating and has continued to and does now endorse and support.

5. That when and if standards of the A. I. E. E. have been further advanced to the stage of being designated as "Approved as American Standard by the American Engineering Standards Committee," they shall continue to be printed as standards of the A. I. E. E. with a statement of approval by the American Engineering Standards Committee added to the title page of each particular standard.

Again on December 10th, 1926 the Board issued a further statement elaborating its previous action of February 9th, as follows:

Inasmuch as American Engineering Standards Committee was in its inception professional in character and a creature of the national professional societies, and

In the belief that the commission to a professional body of the definite responsibility for serving all interests will provoke and insure a spirit of broad cooperation, and

To prevent the possibility of jurisdictional disputes inconsistent with the character of professional and commercial organizations alike, it is moved

That the Board of Directors of the Institute hereby extends its action of February 9, 1926 affecting the preparation and sponsorship for standards under A. E. S. C. procedure to include the following principles.

1. The preferred procedure in the preparation of a standard shall be to commit such duty to the appropriate professional body if any be existent, provided such professional body shall undertake to ascertain the desires of all interested bodies or groups, and so far as possible comprehend them within its standard.

2. In general, sole sponsorship by the appropriate professional body is the preferred means of adoption of a standard under any form of American Engineering Standards Committee procedure.

3. The Board will view with satisfaction any proper steps taken in the direction of effectuating, formally or otherwise, the two foregoing principles.

In line with the action of the Board on February 9th, 1926 and December 10th, 1926, and having for its object the establishment of an organization within the Institute and a procedure which will be in keeping with the traditions and the established policy of the Institute in matters of electrical standards and broadly acceptable to the electric industry, the President, assisted by

members of the Standards Committee and others, has suggested a plan of reorganization of the Standards Committee and modifying the procedure as follows:

Organization and Procedure

Explanation: The object sought is the establishment of an organization within the Institute and a procedure which shall be in keeping with the Institute and a procedure which shall be in keeping with the traditions and established policy of the Institute in matters of electrical standards and broadly acceptable to the electrical industry.

Organization: The Standards Committee will consist of 40 members appointed by the President as follows:

20 from the membership of the Institute at large

10 members of the Institute nominated by the N. E. M. A.

10 members of the Institute nominated by the N. E. L. A.

The President shall appoint the chairman and secretary.

Note: It is recognized that the N. E. M. A. and the N. E. L. A. do not completely represent the manufacturers and users. Therefore the President, in appointing the first mentioned 20 members, will provide, as far as practicable, for representation of the other interests.

From the first mentioned 20 members the President shall appoint at least one member to membership on each of the Institute's technical committees and three delegates and three alternates to constitute the Institute's delegation on the Main Committee of the A. E. S. C.

Executive Committee: The Chairman, the Secretary, and three other members of the Standards Committee designated by the President will constitute the Executive Committee of the Standards Committee. The function of the Executive Committee shall be to handle and direct such matters as may be specifically assigned from time to time to it by the Standards Committee. All acts of the Executive Committee shall be reported to the Committee at its next subsequent meeting for final approval.

Meetings: The Standards Committee shall hold meetings at intervals of not more than two months. The Executive Committee shall hold meetings at such places and at such times as may be necessary to facilitate the general administrative work of the Standards Committee.

Procedure. The initiation of a standard or the preparation or the revision of a standard may be made by any group regarded by the Standards Committee as competent, such as:

1—Any Institute Technical Committee.

2—The N. E. M. A., N. E. L. A., A. E. R. A., and any other allied or interested organization.

3—The A. I. E. E. Standards Committee.

When, in due course, a standard, prepared as indicated above, is submitted to the Standards Committee for adoption, a procedure will be adopted to insure its thorough examination and consideration by all interests. When the desires of all interested bodies or groups have been ascertained, the Standards Committee will endeavor, so far as possible, to have these desires comprehended within the standard. When, in the opinion of the Standards Committee, this has been accomplished, the Standards Committee, will recommend to the Institute Board of Directors, the approval of the standard as an *A. I. E. E. Standard.*

Publication: The standard, when approved, shall be published as the A. I. E. E. Standard and the publication shall include a statement which briefly but clearly will acknowledge the work of the collaborating bodies and individuals.

Approval by A. E. S. C.: When in the opinion of the Standards Committee any Institute Standard should properly be presented to the A. E. S. C. for approval, the Standards Committee shall recommend to its Board that procedure be undertaken in accordance with the Board action of February 9, 1926.

Relation to A. E. S. C.: In the case of standards which are partly electrical and partly concerned with some other field of engineering, the Institute Standards Committee shall employ A. E. S. C. procedure as set forth in the A. E. S. C. Constitution, either accepting sole sponsorship for the A. I. E. E., or agreeing to the sole sponsorship of one of the other professional societies.

For all electrical standards the Institute is instructing its delegates on the Main Committee of the A. E. S. C. to request and accept only sole sponsorship as directed by the Board in its action of December 10th, 1926.

This plan contemplates that if and when it is of vital commercial importance to have a generally accepted standard in the electrical field, the difficult and expensive initial work will be done by some one of the trade associations. The adjustments will be made in the A. I. E. E. Standards Committee, in which the entire electrical industry is represented and which is vouched for by the Institute, one of the great professional engineering societies. When, in the opinion of that committee, the desires of all interests are sufficiently comprehended within the standard, it will be recommended to your Board for adoption as an Institute Standard.

Such a procedure would combine the commercial impetus, the financial resources, the management and the recognition and support of the trade associations with the judicial influences of the professional engineering organization. It is believed that the high character of Institute Standards would be conserved and that the greatly enlarged standardization requirements of the modern electrical industry would be promptly and satisfactorily fulfilled. The Institute would maintain for the conduct of its standardization work an office

staff which would be small but adequate for its part of this work. The Trade Associations would provide the very much greater and more expensive staff facilities for the large amount of work involved in their part of the undertaking.

The acceptability of the standards thus furnished to industry would be due both to the expert specialist effort applied to them under the spur of commercial incentives and to the judicial adjustment procedure to which they would be subsequently subjected under the auspices of the professional engineering society.

For some kinds of standards a trade association of manufacturers could most effectively take the initiative; for other kinds, a trade association of users. The preferable course will be evident from the special circumstances of each case.

It is felt that the A. I. E. E. should be regarded in effect as the authorized representative of the A. E. S. C. for standards in the electrical industry, and adoption as A. I. E. E. standard should not need to be followed by approval of A. E. S. C. in each case. If however, for legal or other reasons, such approval is desirable, the A. E. S. C's constitutional procedure is available as indicated in the plan which has been here presented.

The features which I have tried to emphasize today are:

(1) The great need that Electrical Standardization should be actively and aggressively pushed ahead. Industry and prosperity demand this.

(2) The great prestige of the American Institute of Electrical Engineers as a standards making body—won after 28 years successful experience in this field—is outstanding.

(3) Is the board policy sound, as stated in its Dec. 10, 1926 resolutions, to submit the preparation of a standard solely and preferably to a professional engineering body if any be in existence?

(4) Or is this great organization ready to step aside and surrender the formulation of all electrical standards except those having to do with "Scientific Fundamentals" to the direction of the several trade associations who now feel they are ready to undertake the work?

I have not touched on International Standardization; it is another subject, but is receiving much consideration.

A New Electronic Rectifier

BY L. O. GRONDAHL[1]
Associate, A. I. E. E.

and

P. H. GEIGER[1]
Non-Member

Synopsis.—A new rectifier utilizing a partially oxidized disk of copper as a rectifier unit is described. The disks may be arranged into groups suitable for all fields of rectifier applications.

The rectification appears to take place at the junction between the copper and the oxide without observable physical or chemical changes, and is similar in character to rectification by the hot-cathode type of rectifiers.

The physical characteristics of assembled rectifiers and a method of designing the same for special purposes are outlined and some of the design problems discussed.

It is pointed out that the new rectification phenomenon is of a radically different nature from those observed in structurally somewhat similar contact rectifiers. The usual theories of contact rectification, which are based on electrolysis or thermoelectricity, are not applicable to the present case. The new phenomenon is discussed in the light of more recent theories based on electron affinities of copper and copper-oxide, which are in better accord with the observations.

Some applications are given for which the rectifier seems to be especially suited.

THE present paper is a discussion of the results of a development which has been based on a phenomenon discovered by one of the writers and reported at the meeting of the American Physical Society held at Washington, April 23-24, 1926.[2]

In the course of an investigation of copper oxide formed on a piece of copper, during which current was passed through the oxide in a direction at right angles to the surface of separation, it was observed that the resistance of the combination was less when the current flowed from the oxide to the copper than when it flowed in the reverse direction. In the first unit, the ratio of the resistances in the two directions was about 3 to 1. The phenomenon was so different in nature from anything that had been observed in other known types of rectifiers that an intensive study and experimental investigation was undertaken during which it became more and more evident that the new device has characteristics which make it very probable that it will find general application as a rectifier.

Description

A rectifier element consists of a disk of copper on which has been formed a layer of copper oxide, as shown in Fig. 1. A good electrical connection is made with the exposed surface of the oxide layer by means of a terminal member of soft metal, such as lead or metal foil. The copper disk and the terminal member of soft metal are conveniently made in the form of washers and assembled on a bolt to provide a good connection between the outer surface of the oxide and the soft metal washer.

Fig. 1 shows such an assembly of a half wave rectifier.

In the new rectifier, the rectification appears to be restricted to a microscopically thin layer at the junction between the copper and the oxide, and takes place under entire absence of electrolytic action or other observable physical or chemical changes.

Any number of individual elements may be assembled in series and in parallel into rectifier groups for any desired value of current and voltage. The two standard methods of connecting rectifiers for full wave rectification are shown in Fig. 2. Fig. 3 shows an assembly of four copper oxide rectifier elements into a group for full wave rectification, the connections being the same as in *b* of Fig. 2. Such an assembly may be used without a central tap in the transformer.

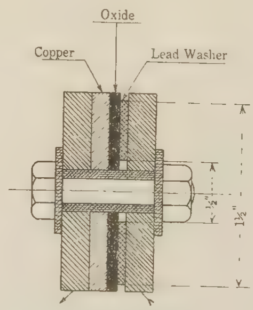

FIG. 1—ASSEMBLY OF SINGLE HALF WAVE RECTIFIER

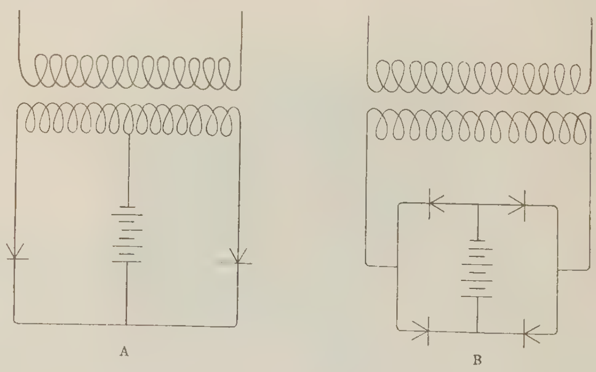

FIG. 2—ARRANGEMENTS OF RECTIFIERS FOR FULL WAVE RECTIFICATION

With good ventilation, such a unit will supply a unidirectional e. m. f. of 6 volts and a current which depends on the area used. The current density that may be used depends on the effectiveness of the ventilation that is provided. In order to dispose of the power lost in the rectifier, it may be provided with ventilating fins as illustrated in Fig. 4. With current densities greater than two amperes per square inch, a forced air

1. Research Department, Union Switch and Signal Company, Swissvale, Pa.

2. L. O. Grondahl, *Phys. Rev.* 27, p. 813, June 1926.

Presented at the A. I. E. E. Winter Convention, New York, N. Y., February 7-11, 1927,

draft or immersion in oil is necessary. A rectifier provided with ventilating fins and immersed in oil has been operated continuously at 3.5 amperes per sq. in. The necessity of making special provision to dissipate the heat developed is due to the fact that for a given capacity, the volume and therefore the radiating surface of the rectifier itself are comparatively small.

Characteristics of Single Rectifiers

Although at first thought the fact that contact is

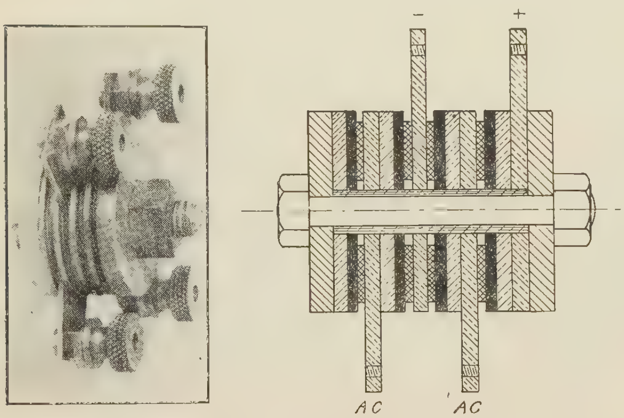

Fig. 3—Assembly of Full Wave Rectifier

made with the exposed surface of the oxide layer would suggest a certain similarity to contact rectifiers such as those of the "cat-whisker" type used in radio, a careful investigation seems to point definitely to the junction between the copper and copper oxide as the seat of rectification. The ordinary "cat-whisker" type contact rectifier has a comparatively high resistance and is entirely unsuitable for the supply of any considerable

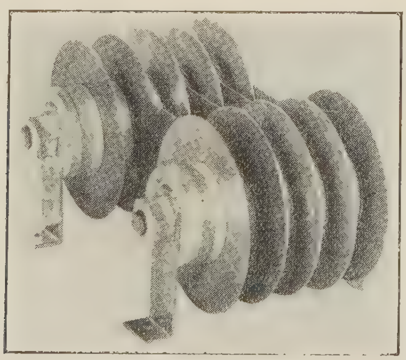

Fig. 4—Assembly Showing Series Parallel Connections used for High Capacities

amount of power. Those who have worked with such rectifiers will realize that the apparatus, even discounting its power limits, is unsatisfactory for most uses on account of the instability of the contact and the erratic behavior of the unit as a conductor. The present rectifier is consistent in its behavior, does not depend on a point contact, and the resistance is so low that the rectifier is capable of carrying large currents. The whole area at the junction between the copper and the oxide participates in the rectification and there is nothing that would suggest the idea of a sensitive spot such as is characteristic of the contact rectifier.

The following curves illustrate the points that are emphasized in the preceding paragraph. Fig. 5 shows the relation between current and electromotive force in the two directions through the copper oxide. In this

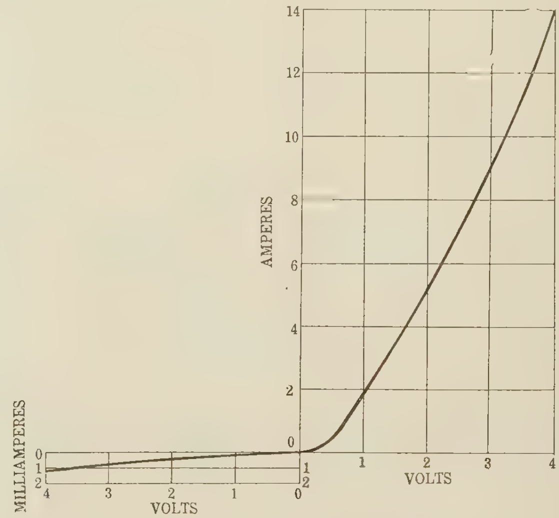

Fig. 5—Current Voltage Characteristics of Copper-Copper Oxide Element

figure, the part of the curve that represents the current in the high-resistance direction has been drawn to a scale 1000 times as great as the remainder of the curve. The scale for currents above the horizontal axis is in amperes; the scale below the horizontal axis is in milliamperes.

Fig. 6 gives the relation between resistance and

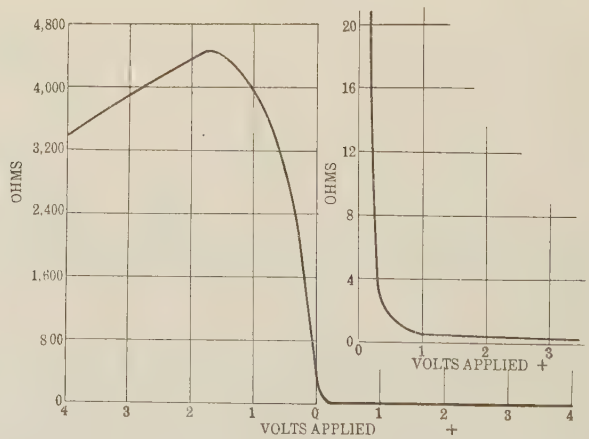

Fig. 6—Resistance Voltage Characteristics of Copper-Copper Oxide Element

electromotive force. The negative values of electromotive force correspond to the high-resistance direction. The resistances approach a common value as the voltage approaches zero. As the voltage is increased from zero, the high resistance increases and the low resistance decreases, at first very rapidly, and then at a decreasing rate as the voltage increases. The low resistance con-

tinues to go down practically along an exponential curve while the high resistance increases to a maximum beyond which it decreases slowly with further increase in voltage. The low resistance is shown in the curve in the upper right hand corner with the scale magnified 200 times. The ratio between the two resistances

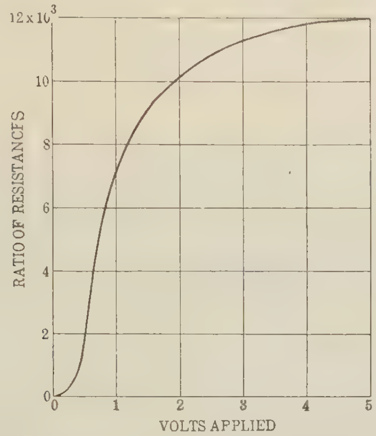

Fig. 7—Relation between Ratio of Resistance and Voltage Applied to Rectifier

increases up to values well beyond those at which the rectifier may be allowed to operate.

The rectification ratio, which is obtained by dividing the low resistance at any particular value of e. m. f. into the high resistance at the same e. m. f., is shown in the curve of Fig. 7. This ratio bears a definite though

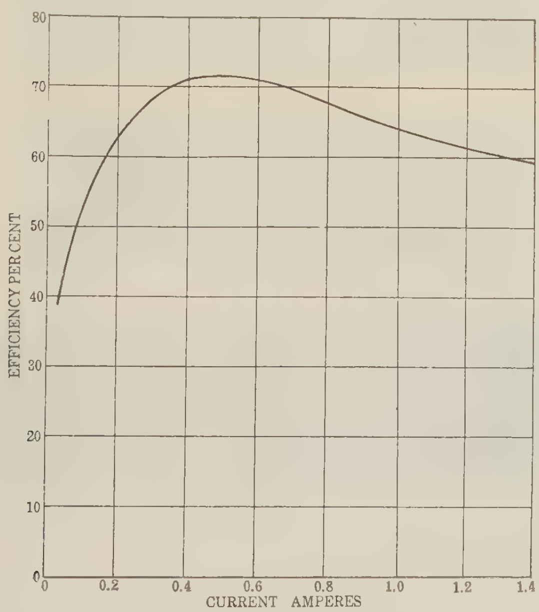

Fig. 8—Efficiency of Full Wave Rectifier Consisting of Four Disks

not a simple relation to efficiency. The relation between the two is complicated by the fact that in practise the voltage across the elements of the rectifier varies from zero to a maximum which is different in the two directions. The efficiency of a full wave rectifier built with four washers is shown in Fig. 8. This is an average unit. The efficiency here shown is the ratio of d-c. watts output to a-c. watts input. True power efficiencies of over 80 per cent have been observed. Since the rectification ratio at very low voltages approaches unity, it follows that the efficiency of the unit as a rectifier at very low voltages approaches zero. At the voltages that are common in the usual applications of a rectifier, the ratio is so high that variations are not often important. A few principles that have to be kept in mind in the design of rectifiers are given below.

Design

For most applications, the losses due to reverse current should be taken into account although they are small. This may be seen from the following considerations.

In a full wave rectifier connected as shown in *b* of Fig. 2, the voltage across each element during the part of

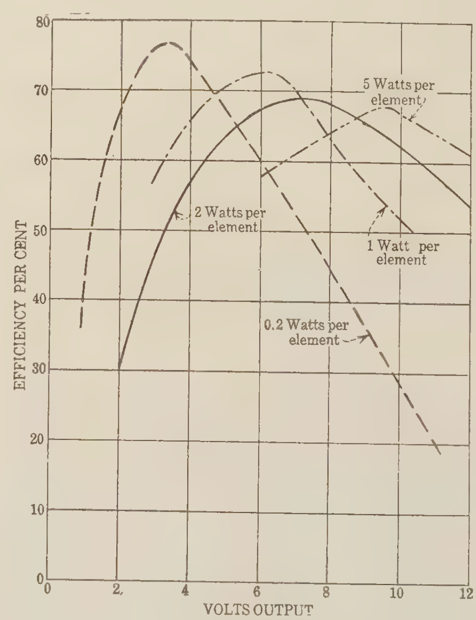

Fig. 9—Efficiency with Various Values of Constant Power

each cycle when the voltage is applied in the high-resistance direction is considerably greater than the voltage applied in the low-resistance direction. Usually the voltage applied in the high-resistance direction is such that the rectifier is working well beyond the maximum of the high-resistance-voltage curve (Fig. 6). For these reasons the ratio of the current in the low-resistance direction to the current in the high-resistance direction is considerably less under actual working conditions, than the ratio as shown in Fig. 7 of the high to the low resistance measured at the same voltage.

Fig. 9 shows the true power efficiency of a rectifier made up of four 1½-in. elements as shown in Fig. 3. The power output was kept constant for each curve, the designating number of each curve being one-fourth the total power output. Points to the left of the maximum efficiency represent an excess of losses in the low

resistance direction; points to the right, an excess of losses in the high-resistance direction. If a given rectifier is used to supply a practically constant output voltage, as is required for battery charging service, the losses in the high-resistance direction remain nearly constant, while the losses in the low-resistance direction decrease with a decrease in charging rate. For this reason, it is sometimes advisable to use a larger number

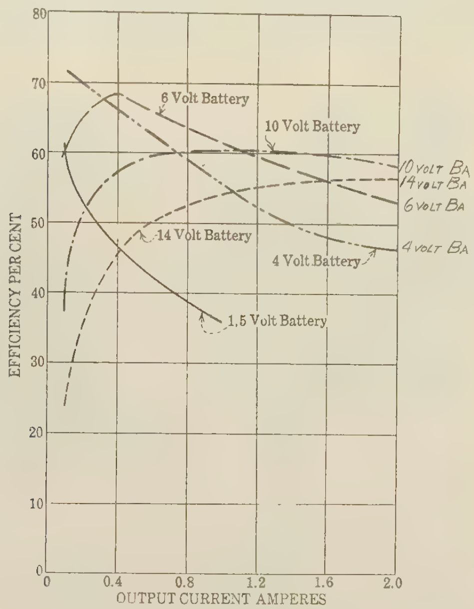

Fig. 10—Efficiency of Full Wave Rectifier used as Battery Charger

of elements for a rectifier with a small output than is required for one with a larger output.

The number of elements required for a given power output depends also upon the method of cooling. The manner in which the elements are to be connected, *i. e.*, the number in series and the number in parallel, may be determined from curves such as those shown in Fig. 9. To obtain maximum efficiency in a complete unit, the number of elements in series between any two terminals of the rectifier is found by dividing the desired voltage output by the voltage giving the maximum efficiency on the corresponding curve. Enough elements are to be connected in parallel to give the desired current output, keeping the output per washer at the value previously decided upon. If the method of connecting that is shown in *a*, Fig. 2 is used, the number of washers in series should be doubled, thereby operating each element on the same portion of the characteristic curve as in the four-cell type rectifier.

For applications requiring a current of a few tenths of an ampere or less, such as supplying the plate current of vacuum tubes, it is sometimes necessary in order to obtain the maximum efficiency to use an element of less than 1½-in. diameter, or else to use a smaller output per washer than would be used in other applications. This can be seen from the curves, for the maximum efficiency (1½-in. washers) occurs at low current values only for the curves of small values of output per element.

Characteristics of Rectifier Groups

Fig. 10 gives the efficiency of a rectifier group used as a battery charger. Since in the charging of a battery we are interested in the average value of the direct current, efficiency is taken as the ratio of d-c. volt-amperes to the a-c. watts, and is less than the power efficiency.

The oscillograms of Fig. 11 show how the relation between the battery voltage and the a-c. voltage impressed on the rectifier affects the wave form of the charging current. These currents result from a combination of the steady battery voltage and the fluctuating voltage supplied by the rectifier. The portion of the cycle during which charging current flows into the battery increases with the increase of the applied voltage.

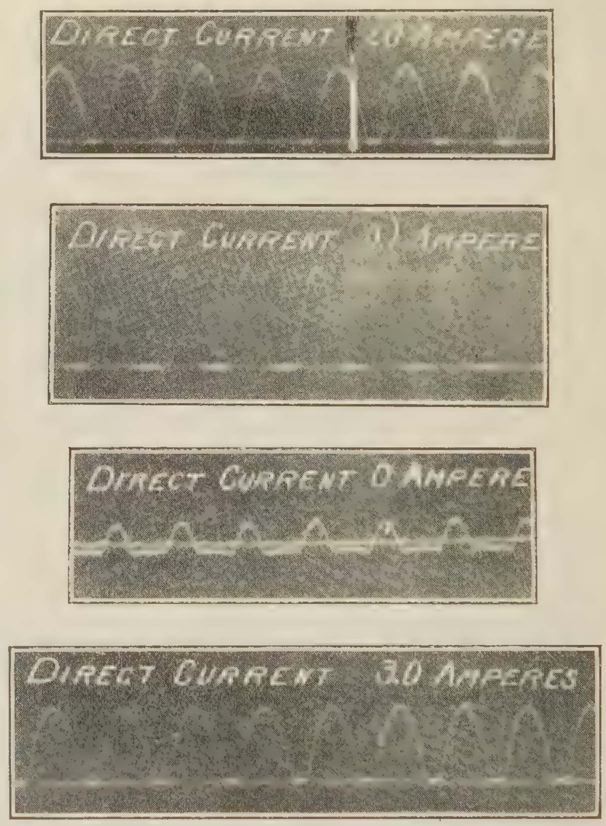

Fig. 11—Oscillograms of Charging Current in Six-Volt Battery with Different Values of A-C. Voltage Applied to the Rectifier

The form factor of the rectified wave has been found to vary in different units between 1.13 and 1.25. The form factor of a pure sine wave is 1.11. The oscillograms of Fig. 12 represent the wave forms of the rectified current from a full wave and a half wave rectifier in a non-inductive load. On account of the fact that the resistance varies with the voltage applied, the low values of current are a little lower than they are in a sine wave. The distortion is barely noticeable.

The rectifier may be used at any ordinary frequency without any effect on its operation. It has been tried with measuring instruments and found to give good rectification up to a frequency of over 3,000,000 cycles per second[3]. Above 100,000 cycles per second, there is a gradual decrease in rectification ratio which may be due to capacity.

The effect of temperature on efficiency may be compensated in various ways and the following is an illustration of what may be done by the proper choice of

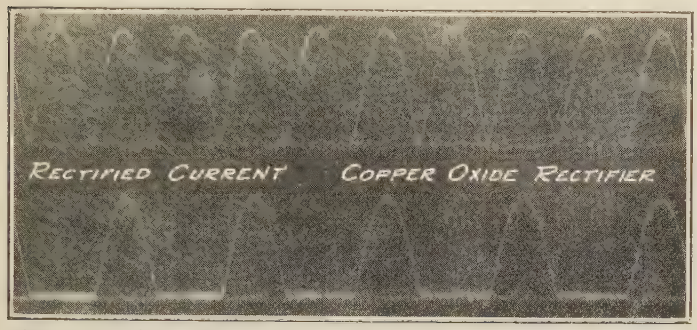

Fig. 12—Oscillograms of Rectifier Currents in Non-Inductive Circuit

the size of the unit and by the use of a reactive ballast. The problem under consideration was to supply a certain constant amount of rectified power at all temperatures from 0 deg. cent. to + 80 deg. cent. with a constant voltage supply. The results are shown in the curve of Fig. 13.

The voltage regulation of a rectifier depends primarily on the effective resistance of the unit. It may be pointed out that just as in a battery of storage cells or of primary cells, the regulation may be controlled by varying the number of cells that are put in parallel, so in the case of this rectifier it is possible to control the regulation. Within reasonable limits, practically any excellence of regulation can be obtained by building into the rectifier the necessary amount of copper. In a test of a rectifier of small capacity, the regulation between no load and full load was changed from 16.5 per cent to 8.5 per cent by doubling the amount of copper in the rectifier.

Theory

While the investigation of the new phenomenon has not yet been carried on to a point where it is fully understood, it is safe to say that it cannot be explained by application to it of the theories which are usually advanced in connection with contact rectifiers.

One of these theories is based on thermoelectricity. Since the oxide in our rectifier is very often not over 0.0015 in. in thickness, it is difficult to imagine any considerable temperature difference between the two surfaces. In addition, experiment shows that the asymmetric resistance is concentrated at or very near the surface of the junction between the oxide and the copper and that the heating of this junction produces an e. m. f. which is in the wrong direction for the rectification that actually takes place. The thermoelectric explanation is, therefore, not tenable.

Another explanation that has been adopted by some physicists is based on electrolysis. This explanation is probably applicable to some contact rectifiers. Where it is applicable, the rectifiers have characteristics that are easily recognized. They require some time after the e. m. f. is applied to reach their steady state. The current is very irregular and shows frequent and very sudden variations. After operation for a comparatively short time, products of electrolysis appear and the rectifier deteriorates. The rectifier under consideration has none of these characteristics. After the application of the e. m. f. it is immediately operative in its steady state. The current is smooth as would be expected with a conductor that has a definite value of resistance for each value of e. m. f. There are no indications of products of electrolysis even after operation for a year or two with current densities of 0.5 ampere to 1 ampere per sq. in. It seems safe to say that the explanation based on electrolysis must be rejected.

Schottky's[4] theory, involving the work required to carry an electron across the boundary between the two substances, also fails to give a satisfactory explanation

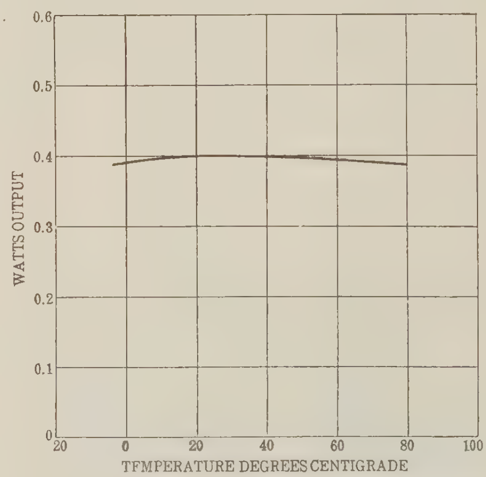

Fig. 13—Output Power at Temperatures between 0 Deg. Cent. and 80 Deg. Cent.

as it is probable that the electron affinity of copper is greater than that of copper oxide.

Jolley in his book on Alternating Current Rectification mentions a theory which assumes a double layer, each half of which is made up of one constituent of the crystal. This condition may exist in the present instance at the surface where the two substances are joined to each other. It may be that beyond the last layer that contains oxygen atoms, there is a layer of

3. Data obtained through the courtesy of the Research Laboratory, Westinghouse Electric and Manufacturing Company.

4. Schottky, *Zeits. fur Physik*, 14, p. 63, March 1923.

copper atoms all, or most, of which are in chemical combination with the oxygen. It is not easy to get a mental picture of the action of such a double layer. It may have value when taken together with the work function considerations.

One of the present writers[5] has proposed a theory based on the fact that the copper and the oxide are in very intimate relationship. The transfer of an electron from copper to oxide, or vice versa, may then take place without passing through the whole potential drop represented by the electron affinity of either substance, but only through a potential drop corresponding to their difference. Under this condition it is conceivable that even at room temperature and without any application of e. m. f. a great number of electrons are able to escape from the copper and into the copper oxide. The copper then serves the same purpose as the hot wire filament in a vacuum tube, and maintains an atmosphere of electrons in the oxide in excess of the normal amount. On account of the short distance between the electrodes, the comparatively large area, and also probably assisted by the dielectric constant of the oxide, the resistance to the flow of electron current in the direction from the copper to the oxide is small.

When the e. m. f. is applied in the opposite direction, there is a tendency to drive the electrons back into the copper. This is opposed by the ready diffusion of electrons from the copper into the oxide so that the electrons become concentrated near the surface of the copper. The resultant gradient in electron concentration in the oxide produces a potential gradient which opposes the flow of electrons in the direction from oxide to copper. This theory seems to fit the voltage resistance curves very well. Experiments are under way which will test it more completely.

Practical Applications

The simple structure, excellent performance and promise of long life of this rectifier make its use in practical applications seem particularly desirable. Engineers are already recognizing and beginning to exploit these characteristics.

In discussing the possibilities of the new rectifier, a prominent engineer suggested the idea of an entire automatic substation in the form of a tank mounted on a pole with the transformer, rectifier, and suitable switches housed in the tank. The complete absence of the requirement of servicing the rectifier, the length of its useful life, which gives promise of being very great, possibly even equal to that of the transformer, make this idea seem very likely to become practical.

The rectifier gives a smooth rectified current which looks very much as though it had been commutated by means of a perfect commutator. It is very constant in its characteristics, requires no electrolyte, and does not involve any moving parts or contacts to be made or broken, in fact, it consists only of parts that are solidly bolted together. It requires no attention or servicing, and can be built into units to meet any reasonable requirement of current and voltage. Each element represents a relatively small increment of current and voltage and they may be assembled into groups just as storage cells are assembled into batteries. The following are meant to be suggestive illustrations, rather than a comprehensive list, of its immediate uses.

1. *Instruments.* A practical use to which the rectifier has been put is in connection with d-c. instruments used on a-c. circuits. Here it is found exceedingly convenient. With a wavemeter, for instance where it has been common practise to use a thermocouple meter, the rectifier is advantageous. A thermocouple takes some time to reach a condition of equilibrium so that after every setting of the wavemeter, the operator has to wait for the instrument to reach a steady state. The rectifier responds instantly and in wavemeter work, therefore, it is possible to proceed very much more rapidly with a rectifier meter than with a thermocouple meter. It is also very sturdy, so that a temporary overload causes no injury to the rectifier. In general, the rectifier with a d-c. instrument is very convenient for reading small alternating currents. As is seen from the curves, the rectifier is not sensitive at low values of power so that there is a limit below which the rectifier is very inefficient. This limit is very low and the instrument can be used satisfactorily down to a few micro-amperes. Here it is important to match the impedances of the rectifier with the instrument and of the rectifier-instrument combination with the source. The impedance of the rectifier changes with the power so that an instrument that is well matched for one range is not necessarily satisfactorily matched for another range. The desired results may be obtained by matching impedances for the lowest range and the scales can be adjusted to take care of the higher ranges.

The direct-current output of the rectifier at low values of power is approximately proportional to the square of the alternating-current input.

For reasonable precision in measuring instruments, it is necessary either to provide temperature compensation for the resistance variations in the rectifier or to choose the constants of the instrument so that the resistance variations of the rectifier are unimportant. This has been done very satisfactorily in special applications. Both the high and low resistance of the rectifier have a high temperature coefficient. The temperature change in the efficiency of a rectifier is due in part to the changes in resistance and in part to the changes in pressure due to the unequal expansion of the bolt and the other parts from which the rectifier is made. Pressure changes may be used to compensate partly for the resistance changes. Compensation may also be accomplished by introducing in the circuit

5. L. O. Grondahl, *Science*, September 24, 1926, Vol. 64, No. 1656, pp. 306-308.

resistances which have an effect that is opposite to that of the rectifier itself.

For use with very sensitive instruments, the rectifier should be protected against illumination. Illumination not only changes the resistance, but produces a small e. m. f. in the rectifier.

2. General Battery Charging. The application of chargers are as numerous as the applications of storage batteries. The automobile starting battery may be used as an illustration since it is very often found

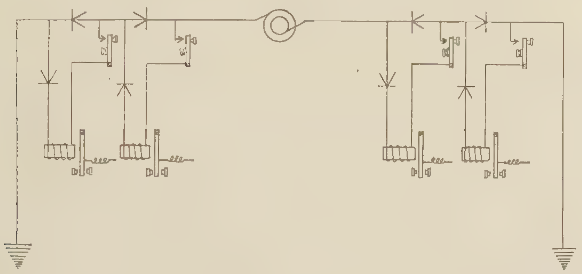

FIG. 14—CIRCUIT ARRANGEMENT USING RECTIFIER FOR DUPLEX TELEGRAPHY

necessary to give it an extra charge. This is usually a very inconvenient thing to do on account of the necessity of getting into the battery case and making the necessary connections. A small transformer and rectifier could be installed either in the automobile or on the wall of the garage with a plug on the instrument board or in some other convenient place so that the connection necessary for charging would be very simple. In such an application, the rectifier is especially practical on account of the fact that it is very sturdy and requires no attention. The charging of telephone and other storage batteries may be arranged as desired in accordance with the principles already laid down.

3. Control Apparatus. The control of electric circuits is usually accomplished by means of electromagnets. Electromagnets are more easily operated by means of direct current than they are by means of alternating current and the provision of a rectifier with each magnet makes this possible. Thus, for instance, d-c. switch magnets and circuit breaker magnets can be used on alternating-current lines.

4. Telegraphy. A system of duplex telegraphy has been proposed which is given in outline in the diagram of Fig. 14. This makes it possible by the use of alternating current and a rectifier to polarize the line so that any telegraph line can be duplexed by simply adding a sending instrument and a receiving instrument and four small rectifiers at each station of the line. If the rectifiers are of the half-wave type, the operation of one sending key will transmit the upper half wave, which will be received by the sounder which is associated with another rectifier which also transmits the upper half wave. When the other sending key is used, the lower half wave is transmitted and this operates the sounder at the other end which is associated with a rectifier that transmits the lower half-wave. Such a system seems practical when one can use rectifiers that are reliable and the capacities of which are easily adapted to the purpose in question.

5. Detectors. The rectifier in its usual form is not suitable for a radio detector, but can be used in a similar way in circuits which involve larger amounts of power. For instance, if it is desired to get a current pulse through a transformer by making and breaking the current in the primary, a rectifier can be used to make the pulse uni-directional. In such cases, the rectifier serves the same purpose as a detector on a very much larger scale.

6. By-pass for Field Switches. With motor or generator field switches, provision has to be made to guard against the injurious effects that may result from the sudden release of the energy of the magnetic field. A rectifier connected between the terminals of the switch in such a direction that it opposes the flow of the direct current serves as a low resistance for the inductive surge that accompanies the opening of the switch and is very effective. A very high resistance rectifier may be used since the voltage of the field discharge is great and the energy loss in the rectifier may be made negligible. It is already in use in a number of similar applications for the protection of relay contacts.

7. Edison Direct Current Systems. In Edison direct-current systems a rectifier of this type has peculiar advantages due to the fact that it is static and can be assembled into units of any desired capacity. A large unit might be made up of a number of smaller standard units constructed so that the capacity of the rectifier may be altered as required by the load. Such a rectifier is entirely noiseless and the only moving parts are the fans or pumps necessary to carry away the heat.

8. Radio. An interesting field for rectifier manufacturers has been the radio field. Here again, the rectifiers are used as battery chargers.

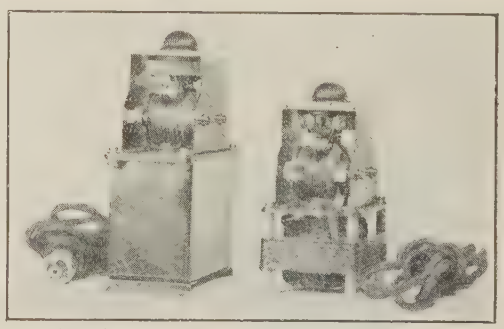

FIG. 15—"A" BATTERY TRICKLE CHARGING UNIT

"A" batteries are very often maintained by what is known as the trickle charge method and tube rectifiers for this purpose have recently appeared on the market. With some "B" battery chargers it is necessary to disconnect the "B" battery and connect the various groups in parallel. The present rectifier can be built in the proper voltage and current capacities to charge either "B" or "A" batteries and to charge them at a

normal rate or at a trickle charging rate as desired. To charge an "A" battery at a trickle charging rate, a small transformer and a rectifier consisting of 4 to 16 copper disks may be used. Such a unit is shown in the photographs of Figs. 15 and 16. The unit may be assembled in a case together with the "A" battery

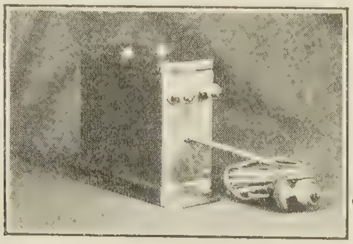

FIG. 16—"A" BATTERY TRICKLE CHARGING UNIT

itself. Rectifiers have been designed to meet the demand for 2 ampere chargers and 5 ampere chargers. A 2 ampere charger is shown in Fig. 17.

A "B" battery charging unit for any e. m. f. up to a 115 volt "B" battery may be had by connecting the

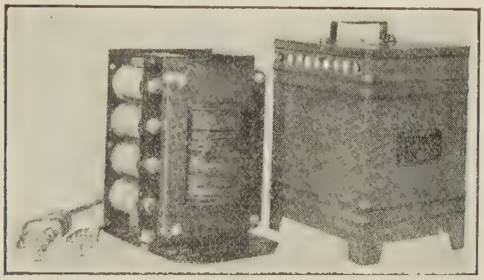

FIG. 17—TWO-AMPERE, SIX-VOLT BATTERY CHARGING UNIT

rectifier with the necessary ballast reactance to the 110 volt house lighting circuit. For a 135 volt battery, it is necessary to use a transformer to step up the alternating voltage. The transformer can be built

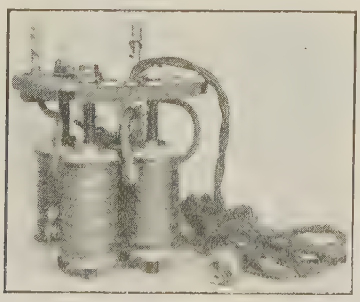

FIG. 18—"B" BATTERY CHARGER

with the necessary reactance so that the size of the unit does not need to be any greater in the second case than in the first. With such a unit, it is only necessary to reverse the switch to disconnect the battery from the receiving set and connect it to the rectifier.

The more interesting application of rectifiers in radio is probably in battery eliminators. For this purpose, the rectifiers have to be built with the necessary voltage and current capacity to supply not only the power to operate the tubes, but the power that is lost in the filter. Units have been built which give satisfactory service as substitutes for both "A" batteries and "B" batteries. Fig. 18 shows the interior of a "B" battery charger, which is the same as the rectifier that is used in a "B" battery substitute.

GENERAL DISCUSSION OF POWER UNITS

Since the units are built up from small elements, the weight per kilowatt capacity is practically independent of the size of the unit. If we take the 1.5-in. washers that are being used at present as our basis for consideration, we find that with proper ventilation, 200 such disks are sufficient to give an output of 1 kw. Two hundred disks correspond to about four pounds of copper and the necessary metal for ventilators and supports is probably equivalent to about 16 pounds more so that the total weight per kw. capacity is about 20 pounds. This weight may be assembled in a space of approximately 400 cu. in. The capacity per cubic foot is, therefore, approximately equal to four kw.

RESEARCH WORK IN ENGINEERING COLLEGES

About fifty American engineering colleges are carrying on organized engineering research. Fifteen of these received during the year 1924-25 more than $500,000 for research through cooperative relations with industry. The total annual expenditure by engineering colleges for research is more than $1,000,000. The cooperative relations between Purdue University and the American Railway Association have resulted in extensive studies for which the association has appropriated more than $500,000 during the last two years.

These statements were made in an address at the annual meeting of the Society of Automotive Engineers by Prof. G. A. Young, head of the school of mechanical engineering, of Purdue University, who asserted that research work carried on by universities has several advantages over that done in industrial laboratories. The workers are free from interruptions, are in an atmosphere that is sympathetic to research, and their work reacts most beneficially in improving the students.

If industry will take its problems to the universities, as is done in Germany, it will be able to secure engineers who will increase the fund of knowledge and develop new processes for the conservation of our resources and for the elimination of waste. Leaders of industry are convinced that research laboratories must be used to acquire new and exact knowledge of facts, to develop new products and to lower manufacturing costs.

Voltage Standardization

Its Relation to the Interconnected Power Companies of the Southeast

BY H. J. SCHOLZ, W. W. EBERHARDT, and S. MURRAY JONES[1]

Associate, A. I. E. E. Associate, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*Voltage standardization has long been recognized as desirable, and to date no definite standards have been accepted and applied. An attempt is now being made to coordinate the recommendations of the different power companies and manufacturers with a view towards adopting definite voltage standards for all apparatus.*

A proposal has recently been submitted by the manufacturers which is not applicable in its entirety to conditions in the Southeast, and this paper contains a counter-proposal submitted as being more readily acceptable to the interconnected power systems of the Southeast.

I. Introduction and Justification for Voltage Standardization

A proposed set of voltage standards appeared in 1922, but lack of cooperation on the part of both manufacturers and operators prevented any general acceptance of them. This was partially due to the fact that insufficient consideration was given to existing apparatus. In 1922 the power companies of the United States were valued at $4,500,000,000, while today they are valued at $9,000,000,000. This tremendous increase, appearing largely as new equipment, indicates the truth of the statement that the longer standardization remains a nonentity, the more complicated will be its final acceptance. Very few operating companies have attempted to eliminate what might be termed off-standard voltages in order to conform to the 1922 standards; in most cases, however, they cannot be justly criticized for this. Time was required for a realization of the savings to be had and as they have grown closer together, the benefits to be derived from standardization have presented themselves. Today most companies are willing to accept any such standards resulting in either financial gains to them or improvements to their service.

No time need be wasted in consideration of standards to be put into effect immediately. No operating company can afford to change its present equipment over night. Standardization in its final form will come about by virtue of a slow influx of semi-standard equipment which, when the absorption is complete, can be operated on standard voltages. This transition period will cover a number of years. Modifications or extensions to present properties made necessary in order to be in accord with any accepted standards must be consistent with proper financing and engineering practises, and any expense incident to such changes must not exceed the monetary values of standardization.

The efficiencies of electrical equipment are in most instances probably as high as will be attained, so that further large economies must be looked for in the development of radically new apparatus, in increasing the load factor of present equipment, and in standardization. The recent acceptance of lamp standards has gone far to bring about the present low cost and greater efficiency of lamps which the public now enjoys. In a like manner, actual savings in the cost of generating and transmission equipment will be evidenced by the standardization of voltages.

It is not to be expected that any expense incurred by carrying out the features of standardization will be returnable immediately in the form of huge savings, but economies will result from the enormous reductions in capital investment required over a long period of time, as compared to what would be necessary were the present policies to continue. The value of voltage standardization has also been emphasized by the benefits which may be obtained therefrom on interconnected systems. Interconnection will be practised more extensively in the future than at present, of course, because of the resulting economies. For example, in the territory covered by the interconnected Southeastern systems there are three distinct water-sheds covering very extensive areas over which the rainfall varies in different rivers in such a way that excess hydro capacity in one section can be used at times to assist systems in other sections in meeting their demands or in filling their storage reservoirs, thereby reducing the amount of reserve steam capacity required and also utilizing water which would otherwise go to waste. In addition to these economies, which are very great, the interconnected systems have been able to improve voltage regulation and service to their customers.

The economic and commercial justification for the standardization of all types of equipment has been proved many times and has ultimately resulted, in practically all cases, in simpler manufacturing methods and a lower cost of the product to the purchaser. There can be no doubt, therefore, as to the feasibility of standardization of voltages by the power companies. Any standards must be adaptable, however, to the large amount of equipment which has already been installed

1. All of the Alabama Power Company, Birmingham, Alabama.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

TABLE I

PRESENT RATED CIRCUIT VOLTAGES ON SOUTHEASTERN INTERCONNECTED SYSTEMS

Southern Power Co.	Carolina Pr. & Lt. Co.	Tennessee Elec. Pr. Co.	Alabama Power Co.	Georgia Ry. & Pr. Co.	Columbus Elec. & Pr. Co.	Central Ga. Pr. Co.
2,300	2400/4150 Y	2,300	2300/4000 Y	2300/4000 Y	2,300	2,300
	6,600					
6,600	7200/12,480 Y	6,600	6,600	6,600	5,500	6,600
			6900/11,950 Y			
11,000	11,000		12,000	11,000	11,000	11,000
13,200		13,200	13,200		12,000	
				19,000		19,000
	22,000	22,000	22,000	22,000		
		33,000		38,000		
44,000		44,000	44,000	44,000		
	60,000	66,000			66,000	66,000
88,000						
100,000	100,000	120,000	110,000	110,000	110,000	110,000

and, to be of any value, must be accepted by the majority of operating companies.

II. General Problems Confronting Southeast in Standardization

Table I gives the present rated circuit voltages of the interconnected companies in the Southeast and shows the conditions to be met in recommending any set of standards. It should be noted here that some of these systems are being operated at voltages slightly higher than those indicated in Table I. A map, Fig. 1, shows the transmission systems of these companies.

Before proceeding further, some of the general problems confronting the acceptance of a set of general voltage standards will be presented, and these problems should be borne in mind when referring to the standards which the writers have recommended as best suited for this territory. The generation in this section during a normal year is approximately 60 per cent from run-of-river hydro plants (some having storage capacity) and 40 per cent from steam reserve plants. The average annual load factor of the hydro electric stations is from 30 to 60 per cent, and of the steam electric stations from 10 to 40 per cent. Generating plants are located both adjacent to, and remote from, load centers, and may be operating during different seasons of the year as base load plants or as voltage boosting stations.

With such operations as outlined above, due mainly to location and types of plants, the annual load factor on the main high voltage circuits is low (approximately 30 per cent) as compared to systems the generation of which is entirely from base load steam plants, or from hydro plants where the river flow is not seasonal. For this reason a higher voltage drop on the transmission

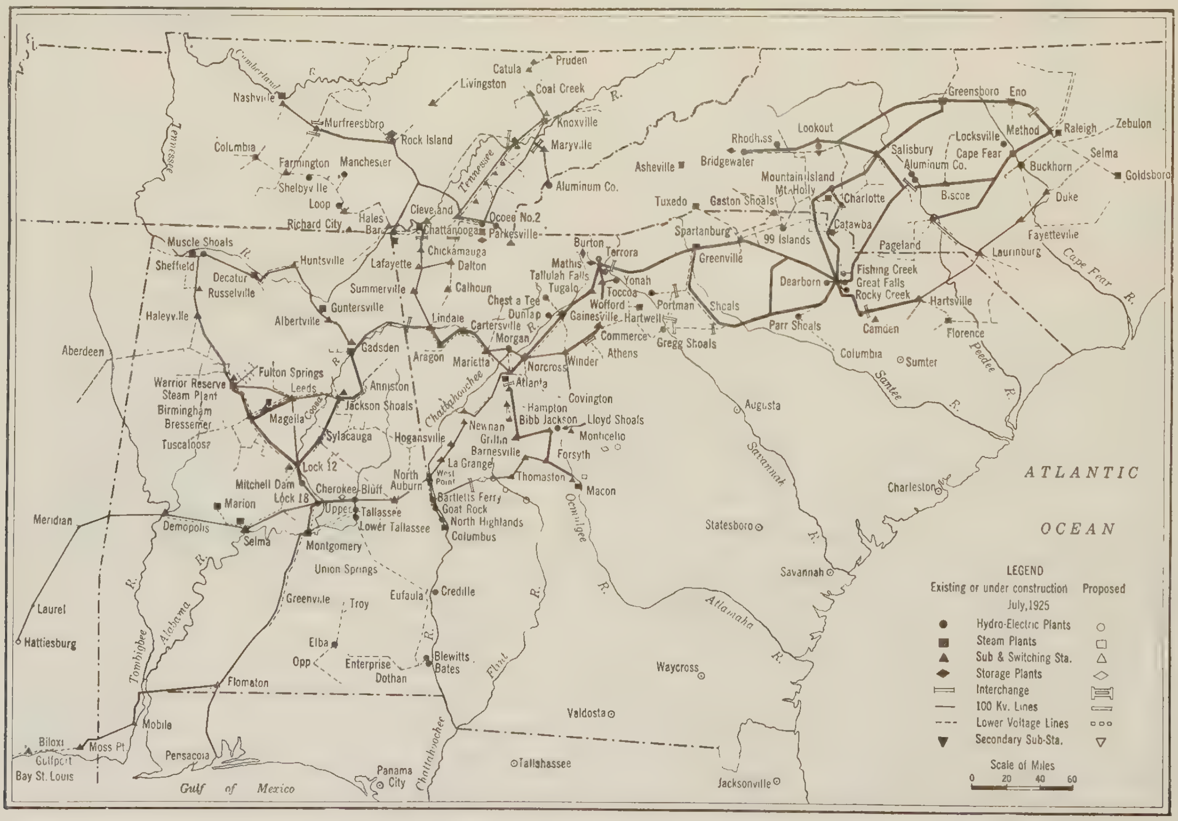

Fig. 1—Transmission Network of Power Systems of the Southwest

circuits may be considered economical and is at present accepted, as compared to that which is economical on lines between base load plants and load centers.

Lengths of transmission circuits and location of substations at many different positions with respect to the generating equipment, prohibits the acceptance of any definite point on the system as a reference for constant voltage except the consumers' bus bars. The receiving voltage at primary substations must be varied according to load conditions on the distribution lines, by regulating the generating units, or by using synchronous condensers to boost or buck the voltage as becomes necessary.

A problem now actively confronting the companies in this territory is that of a rural distribution system, constructed as cheaply as possible, yet flexible enough to meet future demands in the most economical manner. This, in some cases, will call for a set of standards for equipment different from any others. The main problem will be that of suitable transformers having multiple ratios for adaptability on possibly as many as two or three different circuit voltages, and for locations close to the source of supply and at the end of the line.

The above comments will serve the purpose of an outline of the feelings and position of the companies in regard to standardization as a general proposition. In particular, the remainder of this paper covers a detailed analysis of the mechanics of adjustment to any proposed standards. The main problems confronting the companies concerned in this paper are those relative to generation and transmission since the bulk of their power is derived from hydroelectric and steam electric stations situated at a considerable distance from load centers. The problem of working out a set of standards for the lower voltage distribution lines can best be handled, it is believed, by the metropolitan companies the generation of which takes place near the load. Because of the diversity in present practises of equipment of this class, any set of standards satisfactory to such companies could probably be adjusted with equal facility to conditions here.

TABLE II

PROPOSED VOLTAGE RATINGS FOR SYSTEMS, GENERATORS, SWITCHING, CONTROL & PROTECTIVE APPARATUS, TRANSFORMERS, ETC.

Systems	Generators & sync. condensers (see A)	Ind. motors (see B)	Apparatus (see C)	Step-up transformers (see D) Primary	Step-up transformers (see D) Secondary	Step-down transformers (see D) Primary	Step-down transformers (see D) Secondary
	120	110					115
	240	220					230
	480	440					460
	600	550					575
2,400	2,400	2,200		2300/3980 Y	2400/4150 Y	2300/3980 Y	2400/4150 Y
4,150	4,150	3,800					
6,900	6,900	6,600		6,600	6,900	6,600	6,900
7200/12,470 Y*			7,200	6,600	7200/12,470 Y*	6900/11,950 Y	7200/12,470 Y*
11,500	11,500	11,000		11,000	11,500	11,000	11,500
13,800	13,800	13,200	13,800	13,200	13,800	13,200	13,800
23,000			23,000	22,000	23,000	22,000	23,000
34,500			34,500	33,000	34,500	33,000	34,500
46,000			46,000	44,000	46,000	44,000	46,000
69,000			69,000	66,000	69,000	66,000	69,000
92,000			92,000	88,000	92,000	88,000	92,000
103,500			103,500	99,000	103,500	99,000	103,500
115,000			115,000	110,000	115,000	110,000	115,000
138,000			138,000	132,000	138,000	132,000	138,000
161,000			161,000	154,000	161,000	154,000	161,000
230,000			230,000		230,000	220,000	

GENERAL NOTE

Guarantees of efficiency, heating, overload, etc., should be based on the rated voltage of the individual apparatus as shown above. Voltage tests on all equipment should be based on the rated voltage of the circuit on which it is to operate. The rated voltages are in all cases the maximum permissible voltage for continuous operation.

SPECIFIC NOTES

A.—Generators and synchronous condensers should be designed to deliver rated kv-a. output at rated power factor and frequency throughout a range of 5 per cent below and five per cent above rated voltage.

B.—Induction motors should be designed to deliver rated h. p. throughout a range of 10 per cent below and above rated voltage at rated frequency.

C.—Apparatus as here used includes oil circuit breakers, disconnecting switches, current transformers, lightning arresters, insulators, bus bar supports, bushings and fuses; all to be maximum rated. The voltage ratings of potential transformers should be the same as other apparatus with their secondaries rated 115 volts to permit the employment of the now existing even ratios of transformation.

D.—Transformers should be designed and tested for operation on system rated voltages rather than transformer voltage ratings.

a. Step-up transformers should be equipped with the equivalent of three 2½ per cent full capacity taps in the primary winding, two 2½-per cent taps above and one 2½-per cent tap below rated primary voltages.

These taps are necessary to compensate for the inherent regulation of the transformers from no-load to full-load and also to provide sufficient range to make them adaptable to locations remote from, or adjacent to load centers.

b. Step-down transformers should be equipped with the equivalent of four 2½ per cent full capacity taps below rated voltage in the high-tension winding.

*For rural distribution lines.

III. AUTHORS' PROPOSAL

In the September 1926 N. E. L. A. *Bulletin* there appeared a complete set of voltage standards recom-

mended by the manufacturers.[2] These standards are not applicable in their entirety to the present operations in the Southeast. For the sake of simplicity in future discussion they will be referred to and used as a basis for the author's proposed standards which are shown in Table II.

Criticism of the manufacturers' proposed standards is not intended to be destructive, but rather a sincere attempt to show their applicability to the interconnected companies of the Southeast, and to acquaint those interested in this subject with the existing conditions. Quite naturally, comments are more directly bearing on the properties of the Southeastern Power and Light Company since it is with these properties that the writers are most familiar.

It appears to the writers that the manufacturers' definition of rated voltage is satisfactory, namely: "Rated Circuit Voltage: For the purpose of fixing a value to be used in designing and testing electrical apparatus, the rated voltage of a circuit (or system) is defined as the highest rated voltage of the apparatus supplying it. By 'circuit voltage' is meant the voltage from line to line as distinguished from line to neutral. This voltage rating applies to all parts of the circuit. The actual operating voltage of the circuit may vary from the rated circuit voltage but should not exceed it."

The manufacturers' proposed standards would permit a 5 per cent margin above rated voltage for equipment of one class and strictly forbid the employment of such a margin for other classes. The dividing point has been made between 69,000 volts and 88,000 volts to suit the present ratings, and as stated, to prevent any re-design of equipment above 88,000 volts. Restrictions discriminating between classes of voltage serve only to complicate definitions and destroy uniformity in tests and application.

The system rated voltages in the manufacturers' proposal are, with the exception of the first two (2400 and 4150), multiples of 11.5 up to 69,000 volts and beyond this are multiples of 11.0. If the history of the development of these voltage ratings is traced it will be remembered that practically all systems coming within the range of the tabulation started with maximum operating voltages which were multiples of 11.0. The range of operation to take care of peak load conditions was from maximum operating voltages in multiples of 11.0 at the generating end to voltages in multiples of 10.5 at the receiving end. As the load grew and the lines were extended it was necessary to raise the voltage at the generating end to values as high as 11.5 in order to maintain voltages in multiples of 10.5 at the receiving end. In order to accomplish this, it was necessary to over-excite generators and transformers, or, as has been done in recent years, to purchase transformers having taps to give voltages five per cent above the multiples of 11.0. The increase in potential at the source rather than the decrease at the load end of the line has been necessary and justifiable. Many thousands of transformers have been purchased with ratios, for example, of 110/44 kv. with four 2½ per cent taps below normal, in the primary winding. As loads on the distribution circuits were increased it was necessary to maintain higher than 44 kv. on the secondary by over-exciting the transformers. This was undesirable and recently transformers have been purchased having a ratio of 110/45 kv. with five 3 per cent taps below normal in the primary winding which resulted in better voltage at the distribution substations. The higher voltage transmission lines gradually became loaded so that the potential at some substations dropped as low as 100 kv. and with 110 kv. maintained at the generating plants, and primary substation transforners having four 2½ per cent taps below normal in the primary, and connected on the lowest tap, the secondary voltage could not be maintained at its rated value when carrying peak loads. The evolution was the same as in the case of distribution circuits, namely, raising the potential at the source by means of over-excitation, or by the purchase of step-up transformers having taps to deliver above rated voltages. Thus it will be seen that transmission circuits of the higher voltages have already reached the stage where it is desirable that rated voltages should be multiples of 11.5, as are the distribution voltages, and in fact must be such in order to utilize present equipment. It should be remembered, however, that maximum operating voltages in multiples of 11.5 will not occur at all generating stations, but only at those most remote from the load centers. The reason for this will be evident by referring to Fig. 1. In many instances several hydro plants are located on the same stream. Where these plants are distant from the load centers, separate lines from each of them to the load would be uneconomical and hence they are tapped to a group of circuits of one or more lines, extending from the most remote plant to the load.

During extreme emergencies, such as tornadoes, floods, etc., voltage ratings may be exceeded justifiably in order to maintain service; hence all equipment should have sufficient factors of safety to permit short time operation at five per cent above rated voltage. The operating companies should also realize that such practises, although necessary at times, are encroaching on the factors of safety of the apparatus and must be only for short time operation.

It will be noted that a voltage class of 103,500 has been included in the authors' proposed voltage standards. There are two large companies in this section with an installed transformer capacity of over one and a half million kv-a. falling in this class. To select the next voltage class above or below 103,500 volts would involve excessive costs in the rewinding or replacement

2. See also *Voltage Standardization of A-C. Systems from the Viewpoint of the Electrical Manufacturer*, by F. C. Hanker and H. R. Summerhayes, A. I. E. E. Winter Convention, February, 1927.

of these transformers alone, which probably could not be justified.

IV. Generators and Synchronous Condensers

The rated voltages of generators and synchronous condensers, as listed in the manufacturers' proposal would, in general, be acceptable. At present, generators rated 6600 volts are of necessity being operated over peak load hours at 6900 volts. This probably shortens the life of the machine insulation, but since the circumstance prevails, future design at the suggested voltage will prove advantageous. The necessity for operating generators at five per cent above their rated voltage will only occur during emergency conditions. Synchronous condensers where operated on the tertiary of a three-winding transformer bank throughout the range of full leading and lagging kv-a. must of necessity be designed for rated kv-a. from five per cent below to five per cent above rated voltage.

V. Induction Motors

The ratings of induction motors and customers' equipment should remain the same as stated in the manufacturers' proposal, due to the tremendous amount of apparatus at these voltages now in service, and the remainder of the system modified as necessary to maintain these voltages at the customers' terminals.

VI. Apparatus

The term "apparatus" as used in this section is to be interpreted to include oil circuit breakers, disconnecting switches, current and potential transformers, insulators, bushings, bus-bar supports, lightning arresters and fuses. It would seem logical that the above listed apparatus should have voltage ratings exactly the same as the system voltage ratings. The ratings given in the manufacturers' proposal are merely those of present equipment which are adaptable to their proposed system rated voltages. In some instances these are similar to the system voltage ratings and in others they are not. The reason for variations in present ratings is apparently an attempt of the manufacturer to best fit their equipment to the multiplicity of voltages now in use. In order to accomplish the objective in standardizing voltages, the manufacturers would aid materially by rating their apparatus identically with system voltage ratings. This would tend to eliminate the present practise of gradually increasing circuit voltages.

Reference to the manufacturers' published ratings, particularly those for oil circuit breakers, horn gap and disconnecting switches, will show an appreciable variation in the ratings of apparatus for application on circuits of a given voltage. Closer attention should be given to the design and application of insulation in order to secure more uniformity in dielectric strength and flashover values of the various apparatus connected to circuits of given voltage ratings. A complete discussion of this matter and the factors of safety to be given different types of equipment involves entirely too much space to be more than mentioned in this paper, but unquestionably deserves serious consideration.

If the rated voltage is the maximum continuous operating voltage, lightning arresters should be rated the same as other apparatus. At stations where conditions of dynamic and static over-voltages require special design, the voltage rating should be that of the circuit and the nameplate should indicate that they are suitable for one location only. Present lines of apparatus, other than transformers, can no doubt be redesigned and re-rated where necessary to conform to any reasonable set of standards immediately upon their acceptance, without undue burden to either manufacturer or operating company.

VII. Transformers General

The problems relating to step-up and step-down transformers are by far the most important of the entire subject of standardization. The system rated voltages which the authors have recommended have been made after careful investigation of their adaptability to present operations in this territory; likewise the proposed standards for transformers have been based on present operating experience and while they are not suitable for all operating conditions they are believed practical. Transformers to be entirely interchangeable between stations of the same voltage class would require five per cent more taps than indicated in Table II. It is recognized, however, that incorporation of sufficient taps in standard transformers to fulfill every operating requirement would penalize the standards and make them inconsistent with proper engineering practise. Due to this fact it is inevitable that there will always be a demand for certain classes of transformers to meet special operating conditions. The great majority of this special apparatus will be such as can be used on the standard voltages. Although a difference will be found in the high-tension and low-tension voltage ratings for step-up and step-down transformers, their test voltages should be based on the rated circuit voltage at which the equipment will operate and not on the actual primary or secondary voltage rating. The following comments apply especially to two-winding transformers, but three-winding transformers should come under the same classification of ratings, except that in most cases they will require special design due to short-circuit conditions or reactance requirements between windings when one winding is used for the operation of a synchronous condenser.

The voltage ratings of transmission and distribution transformers must be such that they will dovetail together to form a well balanced system from the generators to the consumer. Fig. 2 illustrates present operating practise and the application of the proposed voltage ratings of generators, step-up and step-down transformers.

Under present conditions with generators over-excited five per cent, it is permissible to take only a seven-per cent voltage drop in the transmission line and eight per cent in the primary distribution circuits. This limitation is due to the fact that: first, the generator voltage rating is the same as the rating of the primary windings of step-up transformers, and second, the voltage ratings of step-up and step-down transformers of transmission and primary distribution circuits are alike.

step-down transformers must be changed, necessitating the rebuilding of a large amount of present installed equipment.

VIII. Step-Up Transformers

Only generating station transformers will be considered in this section since it is believed that step-up transformers used in tying two systems together, or for like uses, will be entirely special and dependent upon their location and the purpose which they serve.

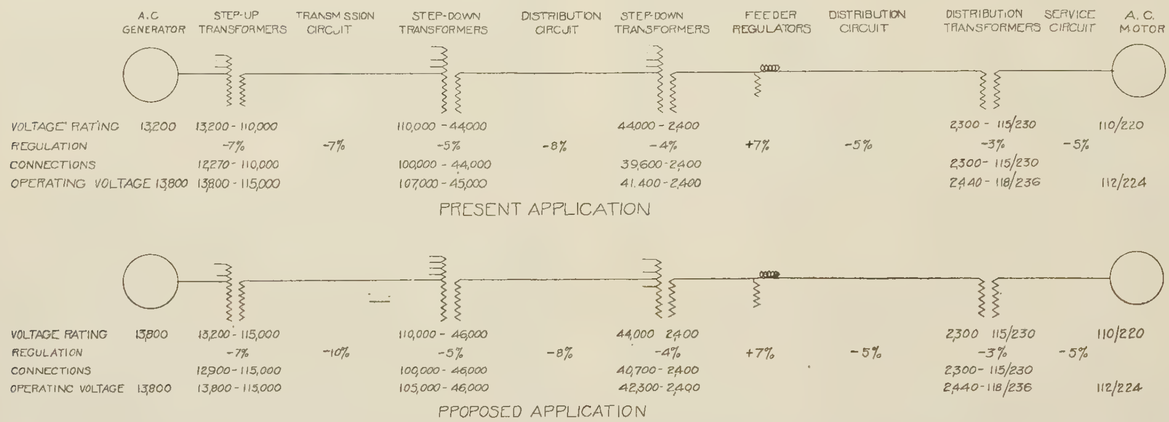

Fig. 2—Present and Proposed Ratings of Generators, and of Step-Up, and Step-Down Transformers, with Illustrations of Representative Applications under Full Load

Recently the Alabama Power Company has purchased step-down transformers rated 110/45 kv. to meet the limitation outlined under Table II and would not hesitate to go a step further to the use of 110/46-kv. transformers, if such a rating is adopted as a standard. In Fig. 2, illustrating the use of the authors' proposed standards, a 10 per cent voltage drop can be allowed in transmission lines and eight per cent in primary distribution circuits without over-exciting the generators. On certain systems in the Southeast it would be easier

Step-up transformers at generating stations in the Southeast will require taps and ratios which will compensate for their inherent regulation and which will be adaptable also for stations located adjacent to, and remote from, the load centers.

A maximum transformer regulation of seven per cent will be assumed in further discussion. This figure should be sufficiently high to include the majority of step-up transformers purchased. One case where higher than seven-per cent regulation may occur is at

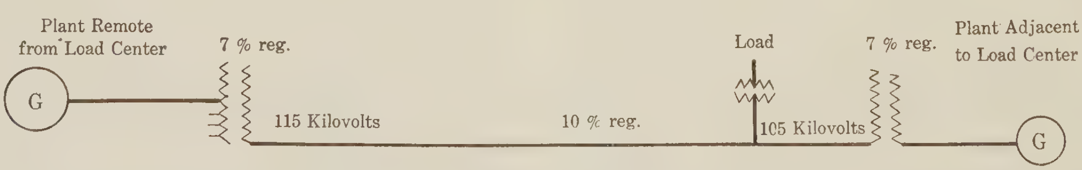

Fig. 3—Diagram Showing Step-Up Transformer

The generators are rated 13.8 kv. The transformers are rated 13. 2/115 kv. and their primaries (low-voltage side) have two 2.5-per cent taps above normal and one 2.5-per cent tap below normal. They have 7 per cent regulation. At full load the generator at the remote plant operates at 13.8 kv. The 12.9-kv. tap is used on the step-up transformer. With 7-per cent drop in the transformer and 10 per cent cut in the line, the voltage at the load is 105 kv. The generator near the load operates at 13.5 kv. and the 13.8-kv. tap is used in its transformer, giving 105 kv. at the load.

to make a transition from present ratings to the standards proposed by the writers, than to meet the standards proposed by the manufacturers because all that is required is an over-excitation of the generators and the operation of step-up transformers at five per cent above rated voltage. The disadvantage of reduced life of insulation of present transformer and generator windings, it is believed, is overbalanced by the operating advantages obtained. If the step-up transformers are operated at a maximum of 110,000 volts, the rating of

seasonal generating plants where during one period of operation the plant is run at full capacity near unity power factor, and a second condition where the plant is carrying rated kv-a. capacity at low power factor, using the generators for voltage boosting.

Fig. 3 is included to indicate the ratios and taps required for step-up transformers on a basis of seven-per cent transformer regulation and 10 per cent maximum line drop. The voltage taps as shown in Fig. 3 will not only compensate for the transformer regulation,

but are suitable for plants located at different points with respect to the load and for seasonal operation.

IX. Step-Down Transformers

Step-down transformers should have ratings and voltage taps for service in locations adjacent to, and remote from, the generating plants and to compensate for their inherent regulation. Step-down transformers will of necessity be shifted from one point on the system to another due to load growth, and should therefore be more flexible than step-up transformers which are rarely moved. The ratings which the writers have recommended will be found to vary from the manufacturers' recommendations only in so far as the changes which have been suggested in the system rated voltages. A maximum regulation of five per cent for step-down transformers has been assumed and this value will seldom be exceeded. The equivalent of four 2½ per cent taps as proposed, while not being sufficient to include all operating requirements, should include a large majority of the transformers purchased.

X. Transformers for Rural Distribution System

Although the problem of rural distribution is comparatively new, experience to date indicates that the most economical circuit voltage for rural lines is 7200/12,470 Y.

The manufacturers' publications state that transformers for this voltage class are given a test from high-voltage winding to low-voltage winding and core of 25,940 volts—(2 × 12,470) plus 1000 volts. On the basis of the proposed definition of "Rated Circuit Voltage," apparatus for rural distribution lines should be rated 7200/12,470 Y, and has been so listed in Table II. The advantage of this rating is that it is a multiple of 2400/4,150 Y, making it possible to use multiple windings on the secondaries of power transformers supplying distribution circuits which can be connected in parallel for 2400/4150 Y or in series for 7200/12,470 Y. This also allows a four-per cent voltage differential between supply transformers and customer's transformers. As the latter have a voltage ratio of 6900/11,950 Y to 115/230, the maintenance of 7200 volts at the supply end makes it possible to maintain rated secondary voltage on the customer's premises without the use of excessive taps on the primary windings of the step-down transformers.

XI. Conclusion

1. The writers have suggested modifications of the manufacturers' proposed standards to make them more adaptable to the interconnected systems of the Southeast. These changes consist of:

a. Addition of 103,500-volt class,

b. Uniform voltage ratings, multiples of 11.5 throughout,

c. Changes in apparatus ratings to make them identical with system voltage ratings,

d. Providing equivalent of one 2½ per cent full capacity voltage tap below normal, and equivalent of two 2½ per cent full capacity taps above normal in the primary winding of step-up transformers to take care of transformer regulation in excess of five per cent, and location of transformers adjacent to, or remote from, load centers,

e. Addition of 7200/12,470 Y voltage class for rural distribution systems.

2. The interconnected power companies in the Southeast are in accord with the proposition of standardization and it is believed that these proposed standards in general would be practicable and acceptable to the majority of operating companies in this section.

XII. Appendix

The appendix will be used for a detailed discussion of the reasons why some of the authors' proposed standards differ from those recommended by the manufacturers, and also to bring attention to instances where special equipment will be required.

A. An analysis of operating reports of companies in the Southeast would indicate many systems operating considerably above rated voltages, and with excessive voltage drop. For example, 110,000-volt systems during peak conditions will be found with voltages as high as 118,000 volts at the remote generating plants and as low as 98,000 volts at remote substations. There are reasons for this, some of which are probably justifiable and others which are not. Needless to say, a 20 per cent voltage drop on any system should not be tolerated except during emergencies, because voltages of 15 and 20 per cent above ratings of equipment not only shorten the life of insulation but encroach on the factors of safety.

In the standards proposed herein a 10 per cent voltage drop on transmission circuits has been assumed as a maximum. This value will be justifiably exceeded in at least one instance in the Southeast. The particular situation is one in which the load center is distant from the source of supply. During the peak hours of the day the load is carried from one set of plants 100 mi. distant, and the remainder of the time it is fed from a different source located some 60 mi. distant. Thus it will be evident that the yearly load factor of the transmission circuits is very low; hence a voltage drop of 15 per cent on these lines, when carrying peak loads, will be found economical. The maximum transmission losses at peak load in this illustration are but 9.8 per cent which, it will be admitted, are not beyond economic limits. The annual losses are approximately 3.0 per cent of the total energy transmitted.

To correct this condition to come within a 10 per cent voltage drop would necessitate one of two things, either the construction of an additional transmission line at a cost of not less than $750,000, or the installation of a $200,000 synchronous condenser station. With

a new transmission circuit, the peak load line losses are reduced to 4.5 per cent and the yearly losses reduced to 1.5 per cent; capitalizing the difference in annual losses based on the power transmitted at 10 per cent would only justify the expenditure of $315,000, hence the line is uneconomical. A synchronous condenser likewise cannot be justified since the transmission losses remain practically the same and the condenser has only corrected voltage conditions.

With a 15 per cent line drop, the standard transformers cannot be used at the remote substations, and units having the equivalent of 15 per cent taps below normal in the primary winding, will be required at an estimated increase in price above standard transformers of from three to five per cent. These transformers are satisfactory, however, for operation at any point on the circuit, and proposed standards have not been penalized by the necessity of these special transformers to fit operating conditions.

B. It is very probable that some of the utilities having a large amount of what may be termed off-standard apparatus in service will be unable to justify a change to meet standards. This is especially true where to abide by the standards would mean lowering present circuit voltages. By reducing operating voltages, the power transmitted over present equipment would be reduced, of course, and the power limit of lines would be decreased. The problem of stability had not been given serious consideration until some few years ago, but as transmission distances have increased and lines become more heavily loaded these problems have been encountered and it is known that lowering the circuit voltage will decrease the static and transient power limits of a line.

A specific example where the reduction of circuit voltages from those recommended by the writers would bring considerable hardship is on the Alabama Power Company's system if it were necessary to reduce the operating voltage on transmission lines from a maximum of 115,000 volts down to a maximum of 110,000 volts. The generating plants with the exception of one steam plant are all remote from the load centers of Birmingham, Bessemer and Anniston. The high-tension voltage at these load centers is, as would be expected, the lowest on the system, and at present varies between 105,000 and 108,000 volts. To reduce this voltage five per cent, as would be necessary were the maximum operating voltage 110,000 instead of 115,000, would require the installation of complete new transformers at these substations. Present transformers have taps as low as 100,025 volts which with 100,000 volts impressed would not give normal voltage on the secondary when operating at full load; thus the voltage must be maintained at approximately 105,000 volts. The total transformer capacity installed at these three substations is 140,000 kv-a. and even granting that these transformers could be rebuilt to deliver rated secondary voltage with 100,000 volts impressed on the primary, which we seriously doubt, without reducing their rating, the expense involved would be unjustified. These stations are at present heavily loaded and of different secondary voltages so that at least two complete new banks of transformers would be required were it possible to rebuild the present units.

Aside from the difficulties involved with transformers if the circuit voltage were to be reduced, such a procedure would involve the immediate construction of some 150 mi. of 110-kv. lines at a cost of not less than $1,500,000, which would hardly be justifiable.

This is only one specific case where the necessity of reducing operating voltages from those recommended would entail considerable hardship; there are several other such examples which could be cited. The only justification for such expenditures would be in the event of the acceptance of 110,000 volts as standard, requiring those companies operating at 115,000 volts to purchase all equipment of the next higher voltage class, but we do not believe that any standards are intended to penalize present operating conditions where there is such a prevalence of equipment now in service which could not be operated on the manufacturers' proposed standards.

If to be in complete accord with any standards involves increasing the circuit voltage, a careful analysis of conditions must be made. If spacings, insulation, corona limit and other electrical factors are satisfactory with increased voltage, the number of customer and other step-down substations must also be considered. The cost of relocation, retiring or rebuilding present transformers must be balanced against the increased carrying capacity of the line at the higher voltage, and decreased losses; also the cost of future apparatus with standard ratings balanced against the cost of off-standard transformers. The increases in costs of special transformers above the price for standard units will have to be given by the manufacturers. It is believed that on lines containing few substations it will be found practical to gradually work toward standard voltages. On other circuits containing numerous substations and customers, and where alterations in station layouts would be necessary to operate on a higher circuit voltage, such changes may not be feasible. These questions will require careful study for each different proposition and hence no definite conclusions can be made.

The most powerful locomotives in the world are beginning their service on the heavy grades of Great Northern Railway through the Cascade Mountains in Washington. Working two units as one, each of these locomotives is 94 ft. long, weighs 715,000 lbs. and can develop 7000 horse power. The freight service on this line over the steep Cascades east of Seattle has been a severe drain on both the resourcefulness and equipment of the road. For years steam engines have been aided by electrics but this has necessitated so much lost time cutting the locomotives into and out of 80-car trains that complete electrification has been adopted.

Measurement of Telegraph Transmission

BY H. NYQUIST[1] R. B. SHANCK[1] and S. I. CORY[1]

Member, A. I. E. E. Associate, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*Various factors contribute to impair the quality of telegraph signals. For instance, there may be interfering currents either induced in the circuit or brought in by conduction, the proportioning of the circuit elements may be imperfect or batteries and relays may be out of adjustment. The result in any case is to distort the telegraph signals so that the received signals are not a true copy of those transmitted. The paper describes methods for measuring this distortion and for analyzing the results so as to indicate the nature and extent of the impairment and its probable cause.*

THE object of this paper is to describe methods of making measurements of the over-all transmission efficiency of the common types of telegraph circuit and to explain how the results may be analyzed. The most direct and practical method of measuring the efficiency of such circuits consists in determining the lengthening or shortening of the dots, dashes and intervening spaces comprising the signals by comparing the signals delivered by the receiving relay with the sent signals. This paper will be limited to a discussion of this effect which will be called *distortion*, and a description of methods which have been devised for measuring it.

The electrical characteristics of the circuit and the wave shapes of the operating currents are not dealt with in this paper except to the extent that their effects are included in the results of the measurements of over-all transmission efficiency.

In recent years considerable work has been done by engineers of the Bell System in connection with devising and applying convenient and accurate methods and means for making quantitative tests of telegraph signal distortion. This includes comparatively elaborate and refined apparatus intended primarily for laboratory use and simpler devices suitable for field work. The technical staff has made extensive use of the new devices and measuring sets for use by the field forces are now under commercial trial.

Various other methods have been used in the past with a view to testing telegraph transmission and the results obtained have been of considerable value. Since little has been published on this subject, a brief discussion of several older methods will also be given.

General Discussion of Telegraph Distortion

The following discussion applies directly to telegraph circuits employing only two different current values[2] thus including substantially all important long-distance wire circuits with the exception of some submarine cables which are operated with three-current values. It may also be applied to many radio telegraph circuits. Considerable modification would be required in order to adapt the ideas outlined herein to the case of circuits employing three or more different current values.

The operation of telegraph circuits by hand or machine involves impressing signals comprising parts of different length or duration at the sending end of the circuit and the reproduction of these signals at the receiving end. The interpretation of these signals depends upon the correctness of the length or duration of the individual signal parts, commonly referred to in the case of a two-element system as "marks" and "spaces" (corresponding respectively to the "closed" and "open" positions of the transmitter). Loudness or strength of the local response is practically never a factor in telegraph transmission since in nearly all cases use is made of local circuit arrangements at the terminals which provide sufficient strength and also avoid any change in strength due to variation in the line circuit. Excessive "lag," that is, time required for transmission over a circuit, is objectionable and, in the case of some printer circuits, variation in lag degrades transmission. Consideration of lag is usually not of importance, however.

An ideal or perfect telegraph circuit reproduces signals at the receiving end exactly as they were impressed at the sending end as regards length of the component marks and spaces, and any change in these lengths during transmission may be considered as lowering the quality. Therefore, the departure from perfection of the received signals, *i. e.*, the lengthening or shortening of marks and spaces which occurs during transmission is a measure of the degradation in transmission quality.

Definitions. It has been found desirable to subdivide distortion of telegraph signals into certain components. The main reason for doing this is that the components are largely due to different and distinct causes and require different treatment for their proper control in both design and transmission maintenance work. Fortunately, it is convenient to separate these components in connection with distortion measurements.

In explaining these components let us suppose a given signal such as the letter C in the American Morse code to be sent at regular intervals over a telegraph circuit and suppose that the signal is formed in such a way that each repetition is substantially perfect at the transmitting end. If the distortion of each of the unit marks or dots of a large number of successive signals

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1. Dept. of Dev. and Research, American Telephone and Telegraph Company, New York, N. Y.

2. See *Certain Factors Affecting Telegraph Speed*, H. Nyquist, Trans, A. I. E. E., Vol. XLIII, 1924, pp. 412-22.

Presented at the A. I. E. E. Winter Convention, New York, N. Y., February 7-11, 1927.

is measured at the receiving end and tabulated, it is, in general, found that the distortion differs not only from dot to dot in a given repetition of the signal, but also that it differs from signal to signal for a given dot. Let us obtain the average of a large number of distortions for a given dot and consider each individual distortion as being made up of two components, one the average and the other the individual departure from the average. The average distortion of a given part of a large number of successive signals will be called the *systematic* distortion. The individual departure of one distortion from the average will be called the *fortuitous* distortion.

It is found of great value to subdivide the systematic component of the distortion still further. To understand this subdivision, assume that we are dealing with a telegraph system in which markings and spacings are sent by means of currents which are equal in magnitude but opposite in sign. It is, of course, possible with such a system to transmit the marking by means of negative current and the spacings by means of positive current, or vice versa. The change from one method of transmission to the other is accomplished by interchanging the positive and negative batteries at the transmitting end and at the same time interchanging the connections to the marking and spacing contacts of the receiving relay.

Now let us assume that the systematic distortion is brought about by the fact that the positive battery at the transmitting end is stronger than the negative battery. Further, let us assume that the circuit is such that this will result in lengthening of the marks when positive current is used for transmitting marks. Then, when negative current is used for transmitting marks, shortening the marks by substantially the same amount will result. When the systematic distortion is of such a nature that interchanging the functions of the two current values employed changes the sign of the systematic distortion but not its magnitude, the distortion will be referred to as *bias*, inasmuch as it indicates a lack of symmetry in the circuit.

Now assume a similar telegraph system in which the battery voltages are equal but which gives rise to distortion due to the fact that the current at the receiving end of the circuit is slow in building up. If the current does not have time to reach its final value on the short impulses, the first dot following a long space may be shortened. In this case it is obvious that interchanging the functions of the positive and negative current does not alter either the sign or the magnitude of the resulting distortion, the first dot of the C signal being shortened whether it is formed by means of positive current or negative current. If the systematic distortion is such that it changes neither sign nor magnitude on interchanging the functions of the two current values employed, it will be called *characteristic* distortion.

In general, it will be found, in measuring the systematic distortion, that neither of the two simple conditions considered above exists by itself. When the functions of the two currents are interchanged, it is nearly always found that the magnitude of the systematic distortion is changed but the sign may or may not be. This phenomenon may be described in a simple manner by saying that both bias and characteristic distortion are present and that the bias is reversed but that the characteristic distortion is not. In other words, it is convenient to say that the total systematic distortion, when the circuit is normal, is given by the expression

$$C + B$$

where C is the characteristic distortion and B is the bias and that with the reverse condition the total systematic distortion is given by the expression

$$C - B$$

The separation of the two components is then easily effected by simply adding and subtracting these measured values of the systematic distortion and dividing by two.

We are now in a position to give a definition of the components of the systematic distortion for the general case. Let us call the systematic distortion measured with the circuit normal S_1 and with the circuit altered so as to interchange the functions of the two current values employed S_2. Then the *characteristic* component is defined as $(S_1 + S_2)/2$ and the *bias* is defined as $(S_1 - S_2)/2$.

It should be noted that, in practically all cases, individual factors which cause distortion do not produce pure bias, characteristic distortion or fortuitous distortion but rather a combination of these. One reason for this is that the effect of a particular factor depends on the extent to which the wave shape has been affected by other factors. Furthermore, distortion produced by a given factor in a particular repeater section depends on the impressed signal combination and this combination is, of course, changed by any distortion experienced previously; this is of importance mainly in connection with circuits made up of a number of repeater sections. As a result, the amount of one component of distortion as determined by the method outlined above depends to a secondary extent on the amount and sign of the other components. Distortion-corrrecting devices such as the Gulstad vibrating circuit[3] also tend to prevent linear addition of increments of distortion. It will be apparent from the foregoing that in order to obtain accurate data on total distortion, measurement should be made over the entire circuit with all components present.

In practical field work it is most generally desired to obtain a measure of the maximum total distortion which may be expected to occur at fairly short intervals. This maximum distortion is reached or exceeded when

3. Described in *Metallic Polar Duplex Telegraph System for Cables*, Bell, Shanck and Branson, A. I. E. E. JOURNAL, April, 1925, pp. 378-386.

comparatively large characteristic and fortuitous components combine with bias in such a manner as to cause a comparatively large total distortion. Since bias is the most readily corrected or neutralized distortion, it is nearly always determined separately.

Many different signal combinations have been used in transmission measuring. The Morse letter C has been used for the most part since this was found to be a fairly severe combination from the standpoint of characteristic distortion. Miscellaneous signals such as occur in actual operation are, in general, preferable to anything else for the measurement of total distortion and are, therefore, used in some methods. For the measurement of bias, the use of "reversals" (a stream of dots and unit spaces) is convenient and gives good approximate data.

Distribution of Different Values of Distortion. It is of interest to note that the distribution of distortions of different magnitude is generally in fair agreement with the normal distribution curve of the theory of probability. This has been shown by results obtained in tests on a number of representative telegraph circuits in the Bell System. A distribution curve showing the quality of telegraph transmission of a particular circuit may therefore be constructed by measuring the total distortion of a number of parts of signals, obtaining the average distortion A, and the probable deviation d from the average. The latter is obtained from the following formula:

$$d = 0.6745 \sqrt{\frac{\Sigma r^2}{N-1}}$$

where N is the number of measurements, r is the difference between the distortion obtained in a particular observation and the average distortion A. The distribution curve may then be plotted from the formula given in Fig. 1.

Fig. 1 shows a typical curve plotted from the results of tests of a particular circuit at a manual operating speed (dotting rate about 12 per second). The basic idea of this distribution curve is that within a particular range of distortion (that is, on the horizontal axis) the probability of the distortion of any particular signal impulse falling in this range is indicated by the area under the curve in that range. Half of the area under the curve is included between the vertical lines drawn at distance d on each side of the vertical line passing through the peak of the curve, it being equally probable that a given impulse will have a distortion within and without this range.

If the distribution of distortion is in accordance with the normal distribution law, the two parameters A and d completely determine the grade of transmission. A circuit with good transmission has small average distortion and a high narrow curve whereas a circuit with poor transmission has large average distortion or a low flat curve or both.

The definition of perfect telegraph signals and the method of specifying the distortion or departure of signals from perfection could be formulated in other ways than that followed in the preceding discussion. However, it is believed that the criteria which have been set forth are very good for manual operation and are fairly good in connection with present printing systems and circuits[4]. As regards the latter, for complete information it would be desirable to determine not only the distortion as defined above but the relative displacement of marks and spaces because synchronism is involved in the operation of these systems.

Effect of Distortion on Operation. A large quantity of data has been collected in connection with tests of different telegraph systems and tests which have been made solely for the purpose of determining the effect

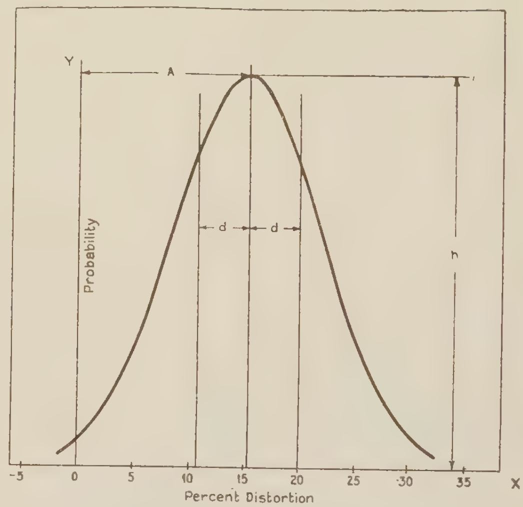

FIG. 1—PROBABILITY CURVE DERIVED FROM TELEGRAPH DISTORTION MEASUREMENTS

Scale of ordinates is so chosen that area under curve is unity. To find probable percentage of all marks or spaces whose distortions fall within a range of one per cent, read off corresponding ordinate from curve and multiply by 100. A = average distortion. d = probable deviation from the average distortion. $y = \frac{h}{\sqrt{\pi}} e^{-h^2(x-A)^2}$

of different amounts and kinds of distortion upon manual and printer operation. The effect of distortion will be discussed only very briefly here, however.

It is thought that the limit which distortion may reach without seriously impairing service is about 35 per cent., as a round average figure, for either manual or printer circuits as used in the Bell System. In order for telegraph operation to be satisfactory, it must, in general, afford communication with very nearly 100 per cent accuracy. In the case of printers, there is no effect whatever until distortion becomes large enough to cause errors. In manual operation, however, the strain on the receiving operator due to distortion, as well as the effect upon accuracy of reception must be taken into consideration.

4. See *Printing Telegraph Systems Applied to Message Traffic Handling*, A. H. Reiber, TRANS. A. I. E. E., Vol. XLI, 1922, pp. 39-51, and *Printing Telegraph Systems*, J. H. Bell, TRANS. A. I. E. E., Vol. XXXIX, 1920, pp. 167-230.

Methods and Means of Measurement

Several methods of observing telegraph transmission quality, which have been employed in the maintenance of commercial telegraph circuits and in the design and development work of the Bell System, will be described below. Generally speaking, methods 1 to 4, inclusive, are older methods in which standard telegraph apparatus is used in connection with making certain observations and accordingly are discussed only briefly. Methods 5, 6 and 7 are newer methods employing telegraph transmission measuring apparatus specially designed for the purpose and will be treated more fully.

The more elaborate and refined methods have been used to advantage in connection with development work on d-c. and carrier telegraph systems including balancing artificial lines and arrangements for minimizing distortion. They have likewise been employed in designing compositing arrangements by means of which telegraph circuits are derived from wires used simultaneously for telephony. In the case of the d-c. metallic telegraph system,[5] it is believed that it would not have been practicable to evolve a satisfactory design without the use of these or equivalent methods.

The determination of the distortion of telegraph signals as defined above consists essentially in the measurement of comparatively small intervals of time, *i. e.*, very small fractions of a second. For comparatively low-speed operation, that is, at manual speeds and somewhat higher, a reasonable limit of sensitivity of apparatus for measuring differences in time intervals is of the order of about one thirty-thousandth second for refined laboratory tests. For general field work, a sensitivity of the measuring apparatus of about one thousandth second is usually sufficient. These sensitivities are found to be well within the unpredictable variations in circuit performance from time to time.

Measurements of distortion by means of the methods described herein have given results which furnish a good criterion of the quality of telegraph circuits, data thus obtained being, in general, reasonably consistent with observations by highly trained telegraphers in the case of manual circuits, and with printer performance in the case of printer circuits. It will be appreciated that these data, being practically independent of judgment on the part of the observer, are considerably more accurate and dependable than those obtained by older methods in the case of manual circuits. As regards printer circuits, some inconsistency is to be expected, for reasons which were brought out in the discussion of distortion. However, experience to date indicates that relations between the results of measurement of distortion and printer performance are fairly consistent and the new methods should be of considerable value for use in connection with printer circuits.

1. Listening Tests. On manually-operated circuits, the quality of transmission may be observed by means of listening tests. In making such tests, a good sender should send signals at the distant end of the circuit while a competent operator at the receiving end listens to a sounder. The receiving operator then forms judgment as to whether the signals are biased or unsteady and whether transmission is satisfactory or not. Unsteadiness, of course, indicates the presence of considerable characteristic or fortuitous distortion or both. It is very convenient to make these observations since no special apparatus is required. In many cases it can be done without interfering with the normal operation of the circuit.

Experience has indicated, however, that there is considerable uncertainty in connection with such observations since they depend upon personal judgment. Skilled operators with considerable experience in passing judgment on telegraph signals often disagree and a particular operator does not form consistent opinions from time to time. It is, of course, impossible to detect small distortions or differences, as is required in connection with development work. In lining up circuits for service by means of listening tests, improper adjustments may be made in order to overcome faults of the sender or to suit the tastes of individual receiving operators.

2. Meter Observations. Ammeters and voltmeters which are not sufficiently fast to follow all the individual signal impulses faithfully are used to a considerable extent for detecting bias and unsteadiness of circuits when a steady stream of dots and short spaces, or reversals, is sent over a circuit. A measure of the bias is obtained by taking the difference between the meter reading for biased signals and the reading for unbiased signals. The presence of fortuitous distortion is indicated if the meter needle vibrates unsteadily or if sudden deflections occur occasionally. This method is particularly useful in maintaining multi-section circuits, especially those operated at high speeds. It is usually necessary to use the meters in local circuits rather than directly in the line and to take certain precautions to avoid misleading results.

3. Tape-Recorder and Similar Methods. A tape recorder, such as that used in the Wheatstone system of telegraphy, giving a graphic record of telegraph signals has been of considerable use in telegraph transmission investigations made by Bell System engineers but it has been almost entirely superseded by improved testing apparatus. Tape records properly taken and analyzed furnish complete information on the signal distortion (as defined above) and displacement of marks and spaces. The process is complicated and very laborious, however, the results not being available for a considerable time, and the accuracy with available apparatus is not great. However, a quick but rough idea of the quality of transmission may be obtained by merely inspecting the tape records.

In using the recorder, it is preferable to impress a perfect, regularly recurring test signal at the distant end

5. See Note 3.

and take two tapes, one with normal signals and the other with "inverted" signals, that is, with marking and spacing interchanged. A number of signals may then be measured and the components of distortion may then be computed.

Tape recorders have been used in connection with making transmission observations on working telegraph circuits also. Two recorders are employed, one at the sending end of the circuit under test and the other at the receiving end. The effect of transmission over the circuit can be ascertained by comparing received marks and spaces with the corresponding sent marks and spaces.

It has been found practicable with some refinement of standard apparatus to obtain an accuracy of about ± 3 per cent at a speed of 15 dots per second with recorders, corresponding to ± 0.001 second.

A recording voltmeter has been employed to advantage in determining the stability of transmission over telegraph circuits. In doing this, a continuous record is made of received signals while reversals are sent over the circuit. The record will show not only interruptions of material extent but gradual changes in bias.

Other instruments, such as Morse recorders, oscillographs and "undulators," have also been employed for making records to show the quality of signals.

4. Tests With Printers. The start-stop and multiplex printing telegraph apparatus,[6] which is in general use in this country, is adaptable to simple manipulation which gives a very good indication of the quality of transmission for printer operation. A test which is commonly made is a determination of margin of orientation. Another test which is used in some cases is called a determination of bias margin.

In order to explain these tests, certain basic principles involved in the operation of these systems will be briefly outlined using a typical system for illustration. In the typical system, each printer operation requires five units of line time, five impulses being sent, one after the other, from segments on the sending "distributor" and received in the same sequence on corresponding segments of a distributor at the receiving end. The brushes of the sending and receiving distributors, of course, rotate in approximate synchronism. The receiving segments are shortened so that only the middle portion of each incoming signal unit is used for operating the selecting arrangements and, therefore, distortion must exceed a certain amount before there is any effect whatever upon the accuracy of the received message. A phase or "orientation" adjustment is provided so that each segment may be traversed by the rotating brush so as to receive a signal from the line at the proper time. This permits the obtaining of orientation margin by rotating the ring of receiving segments a short distance, first one way and then the other, until errors appear in the printed copy.

6. See Note 4.

In order to obtain a measure of the quality of transmission of the line circuit, the orientation margin is first determined locally and then a similar determination is made with signals transmitted from a distant station. As the printer may be assumed to be operating on substantially perfect signals on the local test, the difference between the margins found in the two tests is a measure of the distortion of the line circuit.

In making a test of bias margin, the printing apparatus is first tested locally; then with the most favorable orientation setting, the signals are biased in one direction and then in the other until errors are noted in the printed record. Similar tests are then made with the distant station sending over the line circuit. Bias may be impressed at the receiving end, in which case the difference between the range which can be impressed without causing failure and the local bias range is a measure of the excellence of the signals as normally received over the circuit. When bias is impressed at the sending end of the circuit, the corresponding difference is a measure of the amount of distortion with which signals could be repeated into the line without causing failure; this test is, therefore, of most value in checking up parts of long circuits.

For printer circuits, this method has the advantage that measurements are made with apparatus identical with that used in operation and the results are readily interpretable in terms of performance. Good data on total distortion for use in connection with printer operation may be obtained with miscellaneous signals. By noting how failure occurs for various signal combinations in the neighborhood of the limits of the range, some information may also be obtained as to the components of the distortion.

5. Bridge Methods of Measuring Systematic Distortion. In this subdivision there will be described arrangements which have been employed advantageously for a number of years in making accurate measurements in connection with development work. These devices are in the form of bridge arrangements in which galvanometers give direct indication of the amount of systematic distortion. Simple computations from readings made before and after reversing certain connections give data on bias and characteristic distortion. These devices do not measure the total distortion and are therefore not well suited to use in connection with transmission maintenance.

As these arrangements are more accurate than any others which have been available, they have been very useful in showing the effect of small changes in circuit elements. With these devices, it is possible to make design tests on single section circuits, whereas, with less refined methods, it would be necessary to use a number of sections to obtain values of the distortion which could be measured.

One of these arrangements requires synchronism between the sending and receiving ends and is, accordingly, generally used in looped tests; that is, where

both sending and receiving apparatus is located at one point. Another arrangement, which is considerably simpler, does not require synchronism and can be used for either looped or straightaway tests.

A. Synchronous bridge arrangement. The synchronous arrangement for measuring systematic distortion employs a differential method in which signals received over the line are compared with substantially perfect signals in a circuit of the Wheatstone bridge type.

The basic principles of this device may be understood from Fig. 2. As indicated, relay 1 is operated by the incoming or distorted signal and relay 2 is operated by a perfect signal which is sent locally. If the armatures of these two relays move exactly together, there will be no deflection of the galvanometer inasmuch as the four outer resistances all have the same value and the four inner resistances are also equal to each other. It will also be seen that if both relays repeat perfect signals, but with a phase difference, the average current through the galvanometer will be zero. (There is no net effect of armature travel time if it is the same for both relays.) If a particular mark repeated by relay 1 is distorted systematically, there will, however, be a preponderance of current in one direction or the other through the galvanometer every time this mark occurs. Now, if a switching device be provided to close the galvanometer circuit only shortly before the beginning of this mark and open it shortly after its end, a slow-moving galvanometer will indicate directly the sign and magnitude of the distortion, provided the bridge is properly proportioned. Measurement of normal and inverted signals and simple computation will, therefore, afford data on bias and characteristic distortion of this part of the signal and similar procedure will give corresponding data for the other parts.

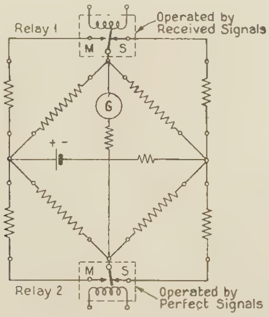

Fig. 2—Synchronous Distortion-Bridge Arrangement

This device has been used for very accurate measurements of the effect of duplex unbalance and some other kinds of interference by sending the interfering current from a distributor running at a speed slightly different from twice that employed with the bridge and noting the maximum deflection of the galvanometer as it swings slowly back and forth. The bridge is readily adaptable also to the measurement of relative displacement of signal parts or lag, as well as distortion, which may be desired, for instance, in connection with printer operation.

Several bridges of this type have been built which are capable of indicating differences in distortion of about one thirty-thousandth second. A multiplex printing telegraph distributor has been adapted to the sending of signals and performing the selecting operations.

For a detailed description of these arrangements, it is suggested that reference be made to U. S. Patents Nos. 1,435,328 and 1,548,059.

B. "E" signal bridge. This arrangement has the advantage of comparative simplicity and portability and also of being usable for straightaway measurements of systematic distortion. It consists of a simple Wheatstone bridge circuit so arranged that the average current through the meter is proportional to the distortion when an "E" signal having a certain ratio of marking to spacing is used. The accuracy is substantially the same as that of the synchronous bridge arrangement.

In applying this method, an "E" signal with, for example, a space four times as long as the mark is sent repeatedly at the distant station and the bridge arrangement shown in Fig. 3 connected to the receiving end so that the bridge relay repeats the incoming signals. When the tongue of this relay is on the marking contact M, the galvanometer current is in one direction and of strength 4; when the tongue is on the spacing contact, it is in the opposite direction and of strength 1; the average is, therefore, zero. A resistance is connected from the tongue of this relay to the right corner of the bridge so as to avoid any effect of time required for the tongue to travel from one contact to the other. The average current through the meter will be such as to cause it to indicate directly the magnitude and direction of distortion of the unit part of the "E" signal when proper voltage is used.

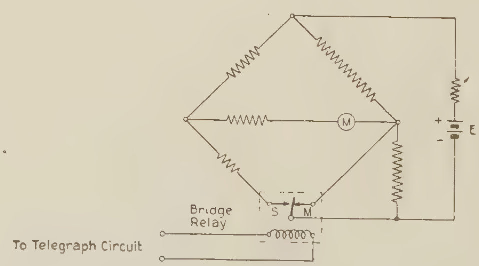

Fig. 3—E-Signal Distortion-Measuring Bridge

It is of interest to note that results obtained with the "E" signal have been nearly as satisfactory as those obtained with more complex signals such as the Morse C.

6. Speed-of-Failure Measurement. The speed at which total failure (100 per cent. distortion) occurs is of interest in connection with telegraph transmission

work. The speed of failure must, in general, be materially higher than the operating speed to provide a margin for variations and in order that the circuit may handle signals which are considerably distorted before being impressed upon the circuit.

The "speed-of-failure meter," the essential features of which are shown in Fig. 4, is a convenient arrangement for obtaining a measurement of the breakdown speed of circuits with a regularly-recurring signal such as the Morse letter C. It may also be used for determining the speed of a regularly recurring signal. As will be seen from the figure, the condenser C is

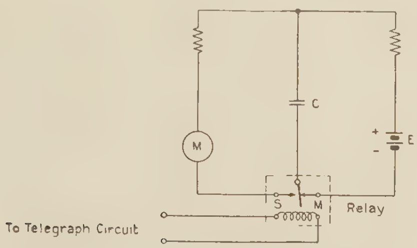

FIG. 4—SPEED-OF-FAILURE METER

charged by the battery E while the relay armature is on marking contact and is discharged through the galvanometer M when the armature is on spacing contact. The time constants of the circuit with the armature on either contact must be small in comparison with the duration of greatly distorted dots and spaces sent at the speed of failure. Then, if a recurring signal is operating the relay at a certain comparatively low speed, the number of impulses passing through the meter is directly proportional to the speed and therefore a slow-moving meter may be made to indicate speed directly.

In measuring the speed of failure, the speed is gradually increased from a low value while the indication of the meter is noted carefully. When the speed reaches the breakdown point, the deflection of the meter, which had been increasing gradually, is suddenly reduced. Although the deflection will then increase further for a time as the speed is increased (until another part of the signal fails), there is no difficulty in noting the breakdown speed with fair accuracy.

7. New Method for Convenient Measurement of Total Distortion. This method, which has recently been devised, allows the quick, convenient and accurate measurement of the total distortion of regularly-recurring signals, including both fortuitous and systematic effects. To accomplish this the problem was approached in a different way from that followed previously, the plan being to provide arrangements which would give a response only when the total distortion of signal parts under observation exceeded a particular amount determined by the observer. As has been brought out, since the distribution of distortions of different value is generally in reasonable agreement with the normal curve of probability theory, a few measurements by this method serve to give fairly complete information regarding transmission performance of a circuit.

Two types of transmission measuring sets have been designed for use in the new method, one of these being a simple arrangement intended primarily for field work and the other a more elaborate device suitable for laboratory tests. These sets are arranged so that a condenser is charged during each mark (or space) and a vacuum tube arrangement provided to give an indication whenever the condenser charge exceeds a predetermined amount. In this way, the amount of distortion which is exceeded with a certain frequency, or the frequency with which distortion exceeds any particular value, may be determined. In addition, the sets are arranged for the measurement of bias separately. Synchronism between sending and receiving apparatus is not required so that straightaway as well as looped tests may be made. Since the principles of operation of the two arrangements are nearly alike, the operation of the simpler type of set only will be taken up in detail.

A. Measurement with field-type set. The principles of this set for measuring total distortion of marks and spaces will be described in connection with Figs. 5 and

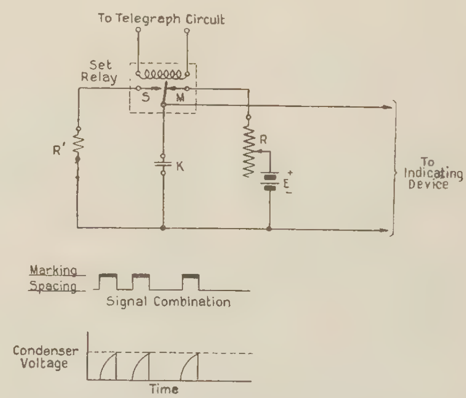

FIG. 5—CIRCUIT FOR MEASUREMENT OF MARKS

6, respectively. Fig. 5 shows a charging and discharging arrangement which produces a voltage across the condenser K, the value of which depends upon the duration of the mark.

Suppose that the relay is operated by an undistorted normal "C" signal, such as is illustrated in the figure. During each mark the condenser K will be charged, as indicated at the bottom of the figure, to a value which depends on the voltage of the battery E and the value of resistance R. It will be practically discharged through the low resistance R' during each space. By suitably proportioning K and R, the voltage across the condenser K can be made to assume, during the time of a mark, any value less than the voltage of the battery.

Now, if one of the marks is distorted, the condenser voltage will be greater or less than that for an undis-

torted mark, depending upon whether the mark is lengthened or shortened. If, for instance, all of the marks are lengthened, the voltage at the conclusion of each mark will be greater than that for undistorted marks.

The voltage which the condenser attains during a distorted mark may be adjusted to the value for undistorted marks by changing the value of resistance R, the amount of change being a measure of the amount of distortion.

As is well known, in a circuit of this type, the voltage

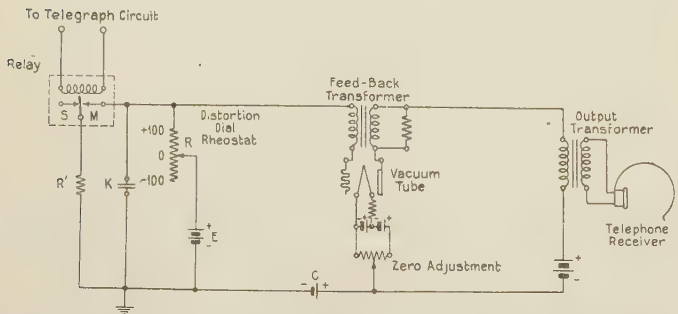

FIG. 6—FIELD-TYPE SET FOR MEASURING TOTAL DISTORTION ARRANGED FOR MEASUREMENT OF SPACES

of a condenser of capacity K, after being charged for time t through a resistance R, equals $\left(1 - e^{-\frac{t}{KR}}\right)$ times the battery voltage, e being the base of Naperian logarithms. If there is a certain percentage increase (or decrease) in time t, the condenser voltage may be brought back to the original value by a corresponding increase (or decrease) in R. Therefore, the change in resistance, expressed as a percentage of the original resistance, is the percentage distortion.

Fig. 6 shows the arrangement of the circuit for the measurement of spaces and includes the essential features of the indicating device. It is seen that condenser K has been connected to the marking contact and the resistance R' to the relay armature, so that the condenser will be discharged during the marking interval and allowed to charge during the spacing interval. The duration of the space thus determines the amount of charge during the spacing interval. The resistance R may be used to control the rate of charge of the condenser and the percentage distortion of spaces determined in the same way as described above in the case of marks.

By reference to the part of Fig. 6 which shows the indicating device, it is seen that the input or grid circuit of the tube is connected across condenser K with a grid-bias battery C in series. The grid-bias voltage is of such value that the plate current is zero until the voltage of condenser K reaches that for an undistorted dot at which time the plate current suddenly increases. This is due to the feed-back effect which is obtained by coupling the input and output circuits of the tube together by means of a transformer. Therefore, the circuit commences to oscillate at an audible frequency whenever the potential of the grid reaches a certain value. This oscillation is allowed to persist for only a short time with the result that a click is heard in a telephone receiver connected in the output circuit whenever the voltage of the condenser exceeds that for undistorted marks.

The arrangements described above are suitable for the measurement of total distortion of marks and spaces of almost any recurring signal combination. In case the signal contains only unit signal parts, as for instance, when measuring the marks of a "C" signal, the distortion indicating dial is set at a position where occasional clicks are present, say several per minute, this value of distortion being taken as the representative maximum lengthening. Now, as the dial is moved towards the negative part of the scale, the clicks will become more and more frequent until a position is reached where clicks are missing only occasionally, this being taken as the representative maximum shortening. When measuring spaces of the "C" signal, undesirable noises are present in the receiver due to the presence of the two long spaces. In some cases this causes difficulty in measuring at high speeds but is not particularly bothersome at manual speeds. If desired these long parts may be measured by adding a lumped resistance in series with the rheostat so that the voltage across the condenser for undistorted parts of the new length is restored to the original reference value.

This set is also arranged to measure directly percentage bias when reversals are used as the test signal, the circuit arrangement for this purpose being shown by Fig. 7. A bridge circuit, containing a meter, is connected

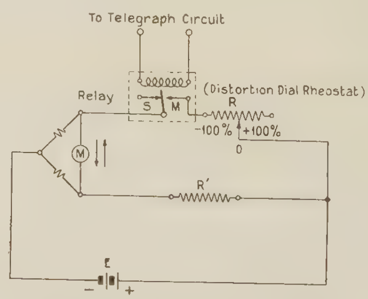

FIG. 7—CIRCUIT FOR MEASUREMENT OF BIAS

to the receiving relay. Equal and opposite currents flow through the meter when the relay armature is on the spacing contact S and marking contact M, respectively, provided that resistance R is one-half of resistance R' and resistances r are small. If the relay is adjusted to repeat unbiased reversals, the average current through the meter will be zero and the meter needle will vibrate through a small amplitude about the zero mark. With biased reversals, the average current through the meter is no longer zero, but it can be brought back to zero by adjusting resistance R. The meter will always indicate zero when resistance R has been adjusted to correspond to the amount of bias, the percentage

change in R, being equal to the percentage bias in terms of an undistorted dot length.

It will be recalled that this relation also holds for resistance R when measuring total distortion so that only one calibrated rheostat is necessary. This rheostat is designed to cover the range from plus 100 to minus 100 per cent., with resistances corresponding to 5 per cent distortion for each step. This is sufficiently close for most field work. Intermediate values may be roughly estimated, however.

Before making a series of measurements, the set is calibrated with substantially perfect reversals. In doing this, the relay is adjusted to repeat the signals unbiased and the vacuum-tube circuit is adjusted so that clicks are just produced in the receiver for about half of the dots. The latter is called the zero adjustment and is accomplished by a slight variation in the grid-biasing potential.

In making a measurement over a circuit the bias is

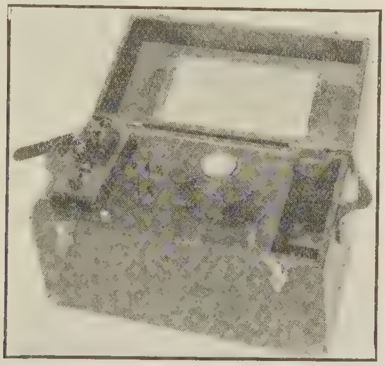

FIG. 8—FIELD-TYPE SET FOR MEASURING TOTAL DISTORTION

first measured, then the marks and spaces of both normal and inverted Morse "C" signals are usually observed to determine the representative maximum total distortion. If desired, a rough idea of the value of the characteristic component may be obtained by measuring the total distortion on both "C" signals and reversals and taking the difference, since in the latter case there is practically no characteristic distortion present.

Fig. 8 is from a photograph of one of the field-type measuring sets. As may be seen both a neutral relay and a polar relay are provided so that either may be used as the receiving relay. The distortion-indicating dial, meter, zero-adjusting dial, switching keys and jacks are mounted on a panel which may be locked. Underneath the panel are mounted the necessary batteries, resistances, condensers, transformers and vacuum tube. A Western Electric 215-A tube which requires only small currents is employed. Accordingly, it is possible to employ a dry cell to energize the filament, and small B batteries. The set is entirely self-contained with the exception of a source of biasing current for the polar relay when receiving with it in an open-and-close local circuit.

B. Laboratory type of measuring set. The essential features of the laboratory type of measuring set are illustrated by Fig. 9. The condenser C_1 corresponds to condenser K of the field-type set and the variable resistance R_1 in its charging circuit corresponds to the distortion dial. Although R_1 might be used for the distortion dial in this case, it has been found more desirable to use a potentiometer P for this purpose. This potentiometer is connected into the charging cir-

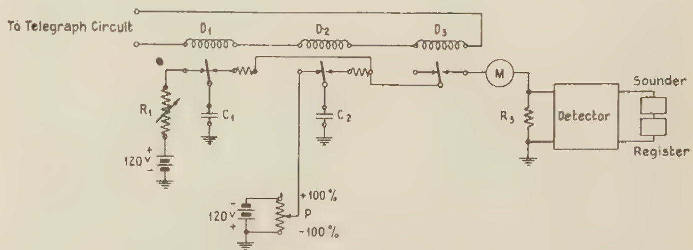

FIG. 9—LABORATORY-TYPE TELEGRAPH TRANSMISSION MEASURING SET

Schematic Circuit Diagram.

cuit of condenser C_2 and permits of varying the applied voltage, and consequently, the value of charge taken by this condenser. For a given battery voltage the amount of the charge stored on condenser C_1 depends upon the length of the mark (or space), but that stored on C_2 depends, for practical purposes, only upon the setting of potentiometer P. At the end of the mark, the two charges are first combined so that they tend to neutralize each other and the residue discharged through the meter M and resistance R_3. These operations are performed in the proper sequence by the relays D_1 to D_3, inclusive. The potentiometer calibration holds true for any particular speed of signaling, provided the resistance R_1 is adjusted to the proper value for that speed.

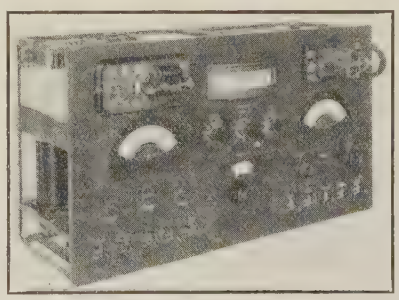

FIG. 10—LABORATORY-TYPE SET FOR MEASURING TOTAL DISTORTION

To measure average distortion of a recurring test signal the potentiometer is adjusted until the meter M indicates zero, under which condition the charges of the two condensers are on the average equal and neutralize each other. By taking readings with normal and inverted signals, the bias and characteristic distortion may be calculated as explained previously. If an "E" signal is used, good results will be obtained

in this manner. However, with other signals the results being average values may be misleading, as positive distortion of one impulse tends to offset negative distortion of others. If reversals are used for the signal, it may be assumed that there is no characteristic distortion and the measurement will give the bias.

To measure total distortion, the detector shown connected across R_3 is used instead of the meter, this detector being responsive only to positive discharges through R_3. Whenever such a charge is impressed across R_3, the detector oscillates momentarily causing operation of the sounder, or register associated with it.

Measurement of total distortion is carried out in much the same manner as in the case of the field-type set. For measurements of maximum lengthening, the charging battery is so connected that condenser C_1 is given a positive charge, while for measurements of maximum shortening, the battery is reversed so that C_1 is given a negative charge. By means of the register data may conveniently be obtained for plotting distribution curves of distortion.

The complete set as shown in Fig. 10 contains numerous switching arrangements to adapt the set to various conditions of measurement. It also includes a speed-of-failure meter. Incidentally the set is provided with an arrangement which can be used to suppress dashes and long spaces so that measurement may be made of miscellaneous printer signals.

The distortion dial is graduated in 2 per cent steps and intermediate values may be estimated. In the measurement of bias and characteristic distortion, the set may be readily adapted to the detection of much smaller differences.

Conclusion

A number of methods have been described for measuring the transmission quality of telegraph circuits. Which method to use in a particular case depends on the circumstances. For the purposes of transmission maintenance, the need has existed for a convenient method of fair accuracy for measuring the total distortion. In this connection it is believed that the method and means described under 7-A above offers considerable promise. Considerable use has been made of this type of apparatus by the development and engineering staffs of the Bell System and experience indicates that it will probably be of considerable value for the following purposes, particularly in connection with manual systems: (1) Obtaining quantitative data with a view of determining whether or not telegraph circuits are satisfactory for service, (2) Making routine checks of telegraph transmission, (3) Lining up circuits for service, and (4) Locating and diagnosing troubles. In the case of printer circuits it should be of most use in connection with item 4.

Computation of the Unbalance Factor
of a Three-Phase Triangle When Lengths of Three Sides are Given

BY A. E. KENNELLY

In an important paper read before the June 1918 Convention of the A. I. E. E., it was shown by Mr. C. L. Fortescue, that any dissymmetrical system of three-phase voltages or currents could be resolved, by vector methods, into a pair of symmetrical systems, one forward and the other backward. The numerical ratio of the latter to the former is called the unbalance factor of the system. Although several vector methods were developed in the paper and its discussion, for evaluating the forward and backward components when the dissymmetrical triangle is given, so far as is known to the writer, no scalar and purely numerical method of developing them has been published. As it is useful sometimes to compute the two components without recourse to vector methods or to the drawing board, a numerical method is here offered.

Let $A\,B\,C$, Fig. 1, be the dissymmetrical three-phase triangle, say of voltages $A\,B = 1100$, $B\,C = 1000$, and $C\,A = 900$, the system having counterclockwise rotation. One of the now well-known vector methods for deriving the forward and backward components is shown. With center A and radius $A\,C$, arcs of 120 deg. and 240 deg. are drawn counterclockwise to the points d_1 and e_1, respectively. Again, with center B and radius $B\,C$, arcs of 120 deg. and 240 deg. are drawn clockwise to the points D and E respectively. Lines $d_1\,D$, and $e_1\,E$, are then drawn as shown. Each of these lines is trisected, as at $d_1\,d_2$ and $e_1\,e_2$. Equilateral triangles $d_1\,d_2\,d_3$ and $e_1\,e_2\,e_3$ are then constructed on these segments. These are known to be the equivalent symmetrical component systems. The equilateral triangle $d_1\,d_2\,d_3$ is drawn with forward rotation or counterclockwise, like $A\,B\,C$, and the equilateral triangle $e_1\,e_2\,e_3$ with reverse or backward rotation.

The vector sum of $d_1\,d_2$ and $e_1\,e_2$ is then equal to the vector $A\,B$,

The vector sum of $d_2\,d_3$ and $e_2\,e_3$ is then equal to the vector $B\,C$,

The vector sum of $d_3\,d_1$ and $e_3\,e_1$ is then equal to the vector $C\,A$.

In this case, the sides of the forward or d triangle measure 996.6 volts, and the sides of the backward or e triangle measure 115.9 volts. The unbalance factor of the $A\,B\,C$ triangle or system is then $115.9/996.6 = 0.116$.

An equivalent numerical method is as follows:

Let A_m be the r. m. s. of the sides of the given triangle

$A\,B\,C$, and let A_s be the side length of an equilateral triangle having the same area as the actual triangle $A\,B\,C$; then the side squares d^2 and e^2 of the forward

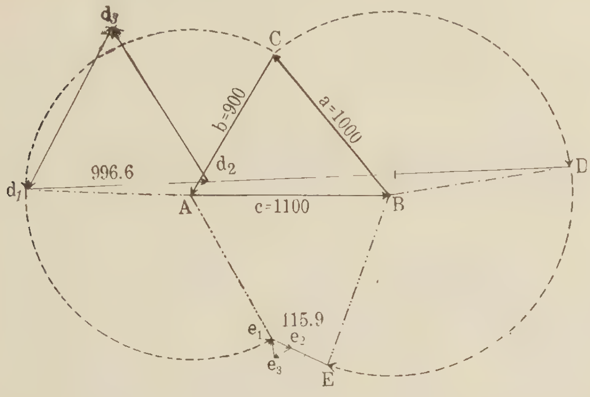

FIG. 1—DIAGRAM SHOWING ANALYSIS OF A DYSSYMMETRICAL SYSTEM. $A\,B\,C$, BY ONE OF THE USUAL VECTOR METHODS INTO FORWARD AND BACKWARD COMPONENTS

and backward components will be respectively the half sum and the half difference of A_m^2 and A_s^2. Thus

$$d^2 = \frac{A_m^2 + A_s^2}{2} \tag{1}$$

and

$$e^2 = \frac{A_m^2 - A_s^2}{2} \tag{2}$$

The unbalance factor is then, as before, e/d.

Let a, b, and c, be the three known sides of the dissymmetrical system triangle $A\,B\,C$. Then the mean square of these sides is:

$$A_m^2 = \frac{a^2 + b^2 + c^2}{3} \tag{3}$$

Again, if the half-perimeter p of the triangle $A\,B\,C$ is

$$p = \frac{a + b + c}{2} \tag{4}$$

it is shown in text-books of plane trigonometry that the area of the triangle $A\,B\,C$ is:

$$s = \sqrt{p\,(p-a)\,.\,(p-b)\,.\,(p-c)} \tag{5}$$

If A_s is the length of the side of an equilateral triangle $A\,B\,C$, Fig. 2, the area S of this triangle, being equal to half the product of the base A_s and the height h, we have

$$h = A_s \cos 30° = A_s\,\sqrt{3}/2 \tag{6}$$

so that

$$S = \frac{h\,.\,A_s}{2} = \frac{A_s^2\,\sqrt{3}}{4} \tag{7}$$

or

$$A_s^2 = \frac{4\,S}{\sqrt{3}} \tag{8}$$

If we take $S = s$, we have

$$A_s^2 = \frac{4\,s}{\sqrt{3}} \tag{9}$$

and A_s^2 is now the side square of an equilateral triangle equal in area to $A\,B\,C$. Then

$$d^2 = \frac{A_m^2 + A_s^2}{2} = \frac{a^2 + b^2 + c^2}{6} + \frac{2\,s}{\sqrt{3}} \tag{10}$$

and

$$e^2 = \frac{A_m^2 - A_s^2}{2} = \frac{a^2 + b^2 + c^2}{6} - \frac{2\,s}{\sqrt{3}} \tag{11}$$

With the given values $a = 1100$, $b = 1000$, and $c = 900$, corresponding to the case of Fig. 1, $A_m^2 = (1100^2 + 1000^2 + 900^2)/3 = 1{,}006{,}666$, or A_m, the r. m. s. side, is 1002.66 volts. The semiperimeter p is 1500 volts, and the areas of the triangle $A\,B\,C$ is $\sqrt{1500 \times 600 \times 400 \times 500} = 424{,}264$. The squared side A_s^2 of an equilateral triangle of this area is, by (**9**), $424{,}264 \times 4/\sqrt{3} = 979{,}796$. or $A_s = 989.846$. We then have, by (**1**),

$$d^2 = \frac{1{,}006{,}666 + 979{,}796}{2} = 993{,}231, \text{ and } d = 996.61$$

volts; while

$$e^2 = \frac{1{,}006{,}666 - 979.796}{2} = 13{,}435, \text{ and } e = 115.91$$

volts.

The unbalance factor, as before, is 115.91/996.61 = 0.1163.

In the extreme case of a symmetrical three-phase system, represented by an equilateral triangle, $a = b = c = q$ say, and the r. m. s. side A_m is also q. More-

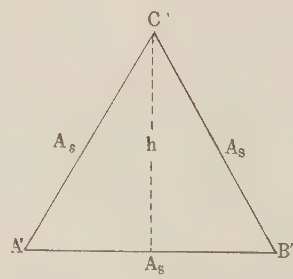

FIG. 2—EQUILATERAL TRIANGLE OF SIDE A_s

over the side A_s of the equilateral triangle of equal area is evidently also q. In that case, $d = \sqrt{\dfrac{q^2 + q^2}{2}} = q$,

and $e = \sqrt{\dfrac{q^2 - q^2}{2}} = 0$; so that the unbalance factor vanishes.

In the opposite extreme case of a flat three-phase system, reduced to the single-phase type; so that $A\,B$, $B\,C$, and $C\,A$ are all in the same straight line, the area of the system triangle vanishes, and so does the side length A_s. Consequently, $d = \dfrac{A_m}{\sqrt{2}} = e$, and e/d, the unbalance factor, becomes unity.

Standardization of Voltage Ratings
For Power Systems and Equipment

BY A. E. SILVER[1] and A. L. HARDING[2]
Fellow, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*This paper undertakes to analyze the voltage practises and requirements of alternating current power systems with the aim of arriving at voltage standards that adequately correct and extend present standards.*

Utilization, or receiving terminals, is taken as the point of reference and for designation of system, circuit and equipment voltages.

For this analysis and development of voltage standards a comprehensive chart, showing operating voltage limits of representative systems, is given in Plate 1. A tabulation summarizing the proposed standard voltage ratings is given in Table XI.

Fundamental Considerations

In the preparation of this paper the authors endeavor to express the results of their experience in dealing with the voltage problems of a number of alternating current power systems well distributed throughout the United States. These systems, while not serving the largest metropolitan areas, do include a wide diversity in size and kind which makes them perhaps representative of usual requirements.

It is not the purpose of this paper to demonstrate the inadequacy of existing standards of equipment voltage ratings, a condition already recognized by manufacturers and operators. Nor is it the purpose to elaborate on the benefits of standardization of equipment voltages. The resultant economy through reduction in a multiplicity of types, through efficiency and convenience in manufacture, in the handling of spare parts, and in flexibility in use, is self-evident.

The purpose of this paper is to develop and propose a schedule of standard voltages believed to meet actual operating requirements and practises in alternating-current power systems. The authors endeavor to deal with the problem without undue adherence to A. I. E. E. or other existing standards wherever experience places the adequacy of any such standards in question. It is believed desirable that in any such standardization, the opportunity be taken to correct inadequacies of this kind.

It must be recognized that many systems, particularly among those that are larger and of pioneer origin, are non-standard, and probably for a long time will continue non-standard, as regards any revised general voltage standards that may be worked out. It seems impracticable to develop voltage standards with sufficient steps to include all of these systems. Some of these will doubtless continue with their individual standards, and move toward general standards only as the opportunity to benefit arises from time to time in the natural course of replacements or reconstruction. Voltage standards, when determined, will in practise, fall short of universal application. They will in effect be schedules of preferred voltages serving as a guide to the maximum practicable uniformity of practise.

The system or class voltages now recognized and established by usage in the United States are as given in Table I.

The inadequacies of present standards of equipment voltages seem to have come about from lack of sufficient appreciation of the relation between voltage levels and functions of a modern power system. For example, take the case of present standard transformers which were developed for distribution service purposes. Many users have purchased these distribution ratio transformers and applied them at supply substations and even for step-up purposes. Experience shows that they cannot be used successfully for all three of these functions. Many of the conditions obtaining on present systems, of equipment operating at voltages seriously in excess of rating, have doubtless come about in this way.

TABLE I
SYSTEM OR CLASS VOLTAGES

115
230
460
575
2300/4000 *Y*
4,600
6600/11,430 *Y*
11,000
7620/13,200 *Y*
13,200
22,000
33,000
44,000
66,000
88,000
110,000
132,000
154,000
220,000

It is reasonable and in accord with operating conditions to define the fundamental reference plane for all voltage standardization of a given class, or the "nominal system voltage," as the mean voltage at utilization terminals, that is, at receiving terminals. This is the plane where the central station company meets the consumer, the "counter" where the product of the industry is delivered. The consumer is interested only in the voltage at his utilization terminals, not at some

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

point in the complex supply system which he does not understand. A power company which purchases its energy is interested in the voltage maintained at the point where it is received, not at some remote point in the system of the transmission company. The present habit of designating system voltage in terms of generation or supply voltage gives an undue appearance of non-uniformity of voltages among systems. This is because generation voltage is used extensively as a means of taking up the voltage "slack" of the system, so that efforts to maintain uniform utilization voltage may bring substantial differences between voltage values at the respective points of generation. The point of utilization is thus the point of practical voltage reference. It is the logical point to establish as nominal or designation voltage.

In the usual power channel between the point of utilization and the source, there are essentially three voltage steps or levels, that of the utilization and distribution zone, that of the high voltage distribution zone, and that of the remote source or transmission zone. In building up a practical schedule of standard voltage ratings for equipment to fit these three zones and to give essentially nominal voltage at receiving terminals, first consideration should be given to actual operating requirements and practises. However, standard equipment ratings now in use should be retained as far as may be reasonably practicable, although this will require that suitable correction be made in some of these standards which now limit effective and efficient power supply under existing and modern methods.

Obviously, standardization in voltages of utilization equipment such as lamps, appliances and motors, where the great bulk of equipment is used, is basic. Voltage standardization for distribution equipment is of next importance, voltage standardization for transmission and high voltage equipment is of least importance. The latter applies in that portion of the system where inequalities can best and most economically be adjusted because units affected are relatively few in number and of large size. It is logical then that a study intended to review, to revise and to better coordinate existing voltage standards should progress from the utilization end of the system.

Utilization Requirements

The basic assumption in this paper is a standard lamp and appliance rating of 115 volts and a standard motor rating of 220 volts. No conclusions are drawn as to the suitability of 115 volts as a lamp standard, as compared with 110, 120 or any other voltage, but rather the 115-volt rating is taken as essentially averaging present usage and recommendations of the National Electric Light Association Lamp Committee. Being a fundamental of voltage standardization, this 115-volt rating should be confirmed or some other thoroughly considered value definitely decided upon. If by reason of further study the 115 volt lamp standard should be changed, corresponding adjustments must be made in those values here given which are built upon this basic value.

In practise small utilization demands are served extensively from combined three-phase motor and lighting secondaries arranged in the 3 wire delta or 4 wire star system. The delta circuits probably constitute the usual distribution arrangement; however, the more recent rapidly extending and advantageous use of 4 wire secondary networks establishes the star system as an important distribution circuit arrangement, particularly in areas of heavy load density. Lamps and appliances of 115 volts, 220-volt motors and distribution step-down service transformers, particularly of the 2300-volt class, are in extensive use on both of these systems. It is essential that standardization be such that lamps, appliances, motors and service transformers can be used interchangeably on both delta and star systems.

Table II indicates voltage conditions obtaining when present utilization equipment designed for and rated at

TABLE II

OPERATING VOLTAGES OF UTILIZATION EQUIPMENT

Average approximate per cent departures from present nameplate rated voltages

Lamp socket or terminal voltage	Lamps rated 115 v	Motors rated 110/220 v	Service transformers rated 115/230 v
110–220 delta	− 5	0	− 3
110–190 star	− 5	− 15	− 3
115–230 delta	0	+ 5	+ 2
115–199 star	0	− 10	+ 2
120–240 delta	+ 5	+ 10	+ 7
120–208 star	+ 5	− 5	+ 7

115 volts (or 110/220 volts for motors) is used at each of the three voltages, 110, 115 and 120. The values in the table give an approximate picture of the necessary excitation range of equipment, without intending any expression as to the correctness of present nameplate ratings in respect to service results. The minimum departures from rated voltage obtain with the 115-230 volt delta and 115-199-volt star terminal voltages considered jointly.

The Distribution System

By definition, as previously noted, nominal system voltage is the mean voltage of equipment at utilization terminals or receiving terminals. It follows that in the ideally designed and operated distribution system nominal voltage of 115 will always obtain at that lamp or appliance so located in the distribution system as to receive the mean voltage of all lamps and appliances, that is to say, the divergence from the standard of 115 volts at the lamp terminals will be the same percentage for that lamp in the distribution system nearest the supply source, as it is for that lamp in the distribution system most remote from the supply source.

A typical distribution circuit comprises house wiring,

service taps, secondary mains, service transformers, primary mains, primary feeders and feeder regulators. To these various parts of the circuit are assigned assumed percentage limits of voltage drop, which are believed to conform reasonably to good practise.

These assigned values of voltage drop for a distribution system are given in Table III.

In developing voltage standard schedules, it is necessary to lay down a background comprising the limits of the various factors that must be covered and coordinated in the spread of such standards. To be worth while, these standards must anticipate future development and growth so far as practicable; that is, standards established now must not only be adapted to present needs but also must be developed with thorough consideration of future needs. Plate 1 is a chart indicating these limits sufficiently, it is believed, to serve as a guide in building voltage standards, at least tentatively, although further survey and analysis of actual conditions is desirable if not essential to final standardization.

Plate 1 includes typical 2300 and 13,200 nominal voltage distribution with primary feeders serving primary load centers, remote from the supply source.

TABLE III

LIMITS FOR DISTRIBUTION SYSTEM VOLTAGE DROPS IN PER CENT

	Heavy load	Light load
House wiring	2.0	0.5
Service tap	1.0	0.25
Secondary main	2.0	0.5
Service transformer	2.5	1.0
Primary main	2.0	0.8
Primary feeder	8.0	2.5

Note: Heavy load is taken at 0.9 power factor. Light load is taken at 25 per cent of heavy load and at 0.75 power factor.

In the 2300-volt portion of the chart, there are assumed distribution or service transformers of the present 20:1 ratio and 115 volts delivered under all loads at the lamp receiving mean voltage. It will be noted that this system requires a variation in voltage at the supply station bus of from 2398 volts at light load to 2674 volts at heavy load, or a mean voltage of 2536.

In the 13,200-volt nominal system shown on the chart, if there are assumed service transformers of the present ratio, 120:1, and 115 volts delivered at the lamp receiving mean voltage as before, there will be required a variation in voltage at the supply station from 14,400 volts at light load to 16,010 volts at heavy load or a mean voltage of 15,200 volts. Obviously, these values are excessive and untenable. For reasons that will be explained more fully later, a voltage of 13,900, that is, approximately 5 per cent above nominal, is considered the upper limit of permissible mean voltage for a distribution system of this voltage class. It follows that a change from the present standard transformer ratio for this class is essential. Assuming a ratio of 110:1, that is, 13,200:120-volt distribution transformers, it will be noted that the system requires a variation in voltage at the supply substation bus of from 13,190 volts at light load to 14,705 volts at heavy load or a mean voltage of approximately 13,900 volts.

Note A: As regards voltage regulation calculations by referring to Plate 1 and Table III, if we call X the per cent voltage drop from the secondary of the step-down service transformer to the mean voltage lamp, then from this lamp the voltage will rise X per cent to the secondary of the service transformer, 2.5 per cent through the transformer and 1.2 per cent back to the primary feeder load center. The lamp having the highest voltage will have the voltage of this load center reduced by 2.5 per cent through the transformer and 1 per cent through the service tap. Similarly the lamp having the lowest voltage will have this load center voltage reduced by $2 + 2.5 + 2 + 1 + 2$ or 9.5 per cent.

Now calling C the percentage departure from normal voltage, for the lamps, we have:

$$+C \text{ (highest voltage lamp)} = (X + 2.5 + 1.2 - 2.5 - 1)$$
$$-C \text{ (lowest voltage lamp)} = (X + 2.5 + 1.2 - 2 - 2.5 - 2 - 1 - 2)$$
$$+C = X + 0.2$$
$$-C = X - 5.8$$
$$X = 5.8 - C$$
$$C = 5.8 - C + 0.2$$
$$C = 3.0$$
$$X = 2.8$$

That is, the lamp having mean voltage will be so located that the voltage drop from the secondary of the service transformer to the lamp will be 2.8 per cent.

It is an important consideration that, next to utilization equipment, step-down service transformers represent the largest single class of standardized equipment in use today on alternating current power systems. It is accordingly essential to practical standardization to utilize these present ratio step-down service transformers, so far as practicable.

As has been shown it is practicable to utilize present ratios in the 2300 volt class. These transformers, now so extensively in use on nominal 2300 volt distribution systems, can be used for delivering rated voltage to standard 115-volt lamps. While this requires increasing the excitation of the transformers above nameplate rated value, it does keep within limits which experience has shown permissible. Reference to Plate 1 will indicate the voltage limits encountered in practise. Adoption of a 120-volt lamp standard would necessitate carrying the excitation of these transformers still higher and probably excessively above the voltage limits for which they are suited. While no modification in present 2300-volt service transformer ratios is necessary and full benefit of interchangeability with existing equipment of this class can be retained, the nameplate rating should be revised to 120-volt secondary, *i. e.*, 2400:120 volts.

For service transformers in the 13,200-volt class, and in fact all distribution classes except the 2300- and 4600-volt classes, new ratios and ratings must be assigned if excessive bus voltages and excessive feeder regulator ranges are to be avoided. As has been shown the proper ratio in the 13,200-volt class is 110:1, 13,200:120, and similarly for other classes.

On the foregoing basis, step-down service transformer ratings as in Table IV are proposed.

From Plate 1 it also becomes evident that feeder regulators, oil circuit breakers, disconnecting switches, lightning arresters and other miscellaneous equipment used on distribution systems, under limiting load conditions may be subjected to operating voltages approximately 10 per cent, and in some cases 15 per cent, in excess of nominal system voltage. The proposed ratings for general apparatus are somewhat adjusted where practicable, in order to retain some existing voltage ratings of this apparatus. It is understood that all equipment, transformers and generators included, is designed for successful operation, with an emergency tolerance of 5 per cent above voltage rating. The proposed ratings closely approximate and in most cases coincide with existing ratings for general apparatus. In practical application some elimination and consolidation to reduce the number of classes may be found feasible. It will be noted also that the proposed ratings extend so as to overlap and include, on the same basis, equipment used in the transmission zone of voltages. As will be shown later, these ratings are suitable for use in the transmission zone.

TABLE IV
PROPOSED STEP-DOWN SERVICE TRANSFORMER VOLTAGE RATINGS

Nominal system or class voltage	High voltage*	Low voltage*
115	..	120
230	..	240
460	480	480
575	600	600
2300/4000 *Y*	2400/4150 *Y*	2300/4000 *Y*
4,600	4,800	4,600
6600/11,430 *Y*	6600/11,430 *Y*	6600/11,430 *Y*
11,000	11,000	11,000
7620/13,200 *Y*	7620/13,200 *Y*	7620/13,200 *Y*
13,200	13,200	13,200
22,000	22,000	..
33,000	33,000	..
44,000	44,000	..
66,000	66,000	..
88,000	88,000	..
110,000	110,000	..
132,000	132,000	..

The high voltage winding has two 5 per cent full-capacity taps except that all taps are omitted in the classes 2300-volt and below.

*All values are at nominal except 4600 volt and below in the high side and 575 volt and below in the low side. These values are raised approximately 5 per cent to more nearly conform to voltages actually encountered in practise.

The proposed voltage ratings for general apparatus are given in Table V.

The receiving voltage at a centrally located supply substation should be logically nominal system voltage as by definition this receiving point becomes essentially a major utilization terminal.

A power company may supply several distribution substations and customer service substations from the same feeder. It is of course not feasible to deliver nominal system voltage to all simultaneously. Assuming a maximum limit of 10 per cent total voltage drop of feeders extending across a major load area and assuming nominal system voltage at the central or mean point of that load area, the feeder voltage at the beginning, or leading edge, of the receiving zone will be at approximately 5 per cent above nominal, the far limits at 5 per cent below nominal.

Under these conditions, it is obvious that step-down transformers at the leading edge of a major load area would operate on full winding, those at the load center would operate on a 5 per cent tap and at the far limits of the area on a 10 per cent tap.

As indicated on Plate 1, in order to maintain constant voltage at the mean lamps, feeder regulators may be called upon to operate between the limits given in Table VI. Present standardization of 10 per cent buck and 10 per cent boost for feeder regulators, is, therefore, reasonably adequate. Without the change in service transformer ratios in the 13,200-volt class, heretofore discussed, a feeder regulator operating range of at least 20 per cent all on the boost side, is required.

Table VI shows conditions imposed on feeder regulators.

It is assumed as the basis of the voltage chart, Plate 1, that constant voltage is held at the supply substation bus at the beginning of the distribution zone, by generator voltage variation. Essentially constant voltage, held by synchronous condensers or otherwise, at some such point imtermediate between utilization and generation, is necessary to avoid a prohibitive corrective range of feeder regulators. The profile on Plate 1 shows the relative values and spread of voltage progressively back through the system, for both heavy and light load conditions.

TABLE V
PROPOSED VOLTAGE RATINGS FOR FEEDER REGULATORS, OIL CIRCUIT BREAKERS, LIGHTNING ARRESTERS AND OTHER MISCELLANEOUS APPARATUS

Nominal system or class voltage	Apparatus voltage rating*
115	125
230	250
460	500
575	625
2300/4000 *Y*	2500/4330 *Y*
4,600	5,000
6600/11,430 *Y*	7500/13,000 *Y*
11,000	12,000
7620/13,200 *Y*	8500/15,000 *Y*
13,200	15,000
22,000	25,000
33,000	37,000
44,000	50,000
66,000	73,000
88,000	96,000
110,000	120,000
132,000	145,000
154,000	170,000
220,000	240,000

*These apparatus voltage rating values are approximately nominal plus 10 per cent.

It should be noted that these profiles are not plotted directly in terms of voltage drop, as customary. Instead, they are plotted in per cent variation from

nominal voltage. The purpose is to bring out more clearly the improved relations maintained between voltage levels and nominal voltage and the corrective benefits throughout the system, gained by utilizing the transformer ratios proposed in this paper. If these voltage profiles were carried back from utilization terminals to generator terminals, using the present standard single ratio transformer throughout, the voltage departure from nominal would be much greater than shown. In fact, the departure from nominal would be increasingly upon the excess voltage side and at the generator terminals would reach 18 per cent above nominal at heavy load and 4.5 per cent above at light load.

TABLE VI
OPERATING VOLTAGE RANGE FOR FEEDER REGULATORS
Approximate per cent buck and boost

Location of regulator (Refer to Plate I)	2300-volt circuits	13,200 volt circuits	
	Present ratio distribution transformers 20:1	Present ratio distribution transformers 120:1	Proposed ratio distribution transformers 110:1
Distribution at end of load area	+ 6.5 (− 12.5)	+ 21.5 (+ 7.5)	+ 14.5 (− 1.5)
Distribution at center of load area	+ 6.5 (− 10.0)	+ 17.5 (+ 5.5)	+10.0 (− 3.0)
Distribution at beginning of load area	+ 6.5 (− 7.5)	+ 13.5 (+ 3.5)	+ 5.5 (− 5.0)
High voltage distribution at end of load area	+ 6.5 (− 6.0)	+ 14.0 (+ 0.0)	+ 6.0 (− 6.0)
High voltage distribution at center of load area	+ 6.5 (− 4.5)	+ 14.0 (+ 4.0)	+ 6.0 (− 4.5)
High voltage distribution at beginning of load area	+ 5.5 (− 2.0)	+ 13.5 (+ 6.5)	+ 5.5 (− 2.0)

The High-Voltage System

The preceding discussion, starting from utilization requirements and working back through the distribution system, determines the necessary bus voltages at the supply substation. If this supply is derived from transmission or high voltage distribution circuits, then the low voltage windings of supply substation step-down transformers must deliver this required voltage.

Plate 1 includes a representative high voltage distribution system (66,000 volts nominal), comprising high voltage service transformers, supply substation transformers, transmission circuits and step-up transformers. Plate 1 also extends further to include a representative transmission system, (132,000 volts nominal), serving this high voltage distribution system from a remote generating source. Generating equipment may be used on any or all of the several supply buses in the composite picture. Many combinations other than those shown on Plate 1 are possible. This chart is intended only to set forth representative limits adequate for voltage standardization purposes.

To the respective parts of representative transmission and high voltage distribution systems are assigned assumed limits of voltage drop as given in Table VII.

These values of Table VII determine the necessary voltage ratings of supply substation step-down transformers at ratios as given in Table VIII.

TABLE VII
LIMITS FOR HIGH VOLTAGE SYSTEM VOLTAGE DROPS IN PER CENT

	Heavy load	Light load
Step-down supply substation transformer	5.0	2.0
High-voltage step-down service transformer	5.0	2.0
High-voltage distribution feeder (to center of high-voltage distribution zone)	5.0	2.0
Transmission line (to beginning of high-voltage distribution zone)	5.0	2.0
Step-up transformer	5.0	2.0

Note: Heavy load taken at 0.9 power factor average, light load taken at 35 per cent of heavy load and at 0.85 power factor average. The values of per cent drop given above also take to account load diversities, power factors, load factors, and line charging characteristics

Plate 1 indicates the necessary voltages on the generating station high-voltage buses which thus determines the high-voltage rating of step-up transformers. The low-voltage rating of these transformers must for standardization purposes be consistent with the voltage rating for generators as described in later paragraphs. The voltage ratings for step-up transformers given in Table IX will satisfy these conditions assuming excitation of the low-voltage winding to be normal when overcoming transformer regulation.

TABLE VIII
PROPOSED STEP-DOWN SUPPLY SUBSTATION TRANSFORMER VOLTAGE RATINGS

Nominal system or class voltage	High voltage*	Low voltage†
2300/4,000 Y	..	2500/4330 Y
4,600	4,600	5,000
6600/11,430 Y	6600/11,430 Y	6900/11,950 Y
11,000	11,000	11,500
7620/13,200 Y	7620/13,200 Y	8000/13,860 Y
13,200	13,200	13,800
22,000	22,000	23,000
33,000	33,000	34,500
44,000	44,000	46,000
66,000	66,000	69,000
88,000	88,000	92,000
110,000	110,000	115,000
132,000	132,000	138,000
154,000	154,000	162,000
220,000	220,000	..

All high voltage windings have two 5 per cent full-capacity and one 5 per cent reduced-capacity taps.

*Rated at nominal.

†4600 volts and below rated at nominal + 10 per cent.
6600 volts and above rated at nominal + 5 per cent.

At a generating station bus a step-up transformer is often used to serve a long high-voltage transmission to a remote load area. A high-voltage rating to provide for 10 per cent voltage drop in transmission seems a reasonable upper limit for standardization purposes.

Step-up transformers will operate normally on taps

when located at the edge of the receiving or load area so that the transmission zone in effect is eliminated.

Table IX provides for the foregoing conditions.

While separate types are proposed to meet the foregoing three functional duties of transformers, it is recognized that by providing a broader tap range with increased iron to enable full voltage excitation on under-voltage taps, any two or all three of these types can be consolidated into a single standard. For example, to consolidate the service type and the supply substation type requires a high-voltage winding rated at nominal voltage with a 15 per cent full capacity tap range and 20 per cent total tap range and capable of normal excitation with full normal voltage impressed on the 95 per cent tap. Similarly, to consolidate all three types requires a high-voltage winding rated at 10 per cent above nominal voltage with a 25 per cent full capacity tap range and 30 per cent total tap range, and capable of step-down duty at normal excitation with full normal voltage impressed on the 85 per cent tap. The extent to which these three types should be consolidated, if at all, in final standards, is essentially an economic problem that must be decided by thoroughly weighing the benefits of interchangeability against the increased cost and other factors concerned.

TABLE IX

PROPOSED STEP-UP TRANSFORMER VOLTAGE RATINGS

Nominal system or class voltage	Low voltage*	High voltage†
115	115	. .
230	230	250
460	460	500
575	575	625
2300/4000 Y	2300/4000 Y	2500/4330 Y
4,600	4,600	5,000
6600/11,430 Y	6600/11,430 Y	7200/12,500 Y
11,000	11,000	12,000
7620/13,200 Y	7620/13,200 Y	8400/14,500 Y
13,200	13,200	14,500
22,000	22,000	24,000
33,000	33,000	36,000
44,000	44,000	48,000
66,000	66,000	72,000
88,000	88,000	96,000
110,000	110,000	120,000
132,000	132,000	145,000
154,000	154,000	170,000
220,000	. .	240,000

All high-voltage windings have two 5 per cent full-capacity taps.
*Rated at nominal.
†Rated at nominal + 10 per cent.

A study of the limits shown on Plate 1 indicates that voltage ratings of oil circuit breakers, disconnecting switches, lightning arresters, and other miscellaneous apparatus as previously shown in Table V meet the requirements and operating practises of the high voltage system.

While the proposed ratings raise the present test voltages for general apparatus in the higher voltage classes, redesign of this apparatus is not necessarily required. Much of this apparatus is now operating successfully at voltages in excess of nameplate rating. In determining test voltages for these various types of equipment, it is assumed of course that designers will make allowance for differences in fundamental characteristics. Furthermore, as rapidly as advance of knowledge will permit, it is essential that the effects of impulse and other transient voltage phenomena be taken to account.

Generation Requirements

Generators, in many and perhaps the usual cases, deliver directly into supply buses and may operate at fixed voltage with feeder regulators or at variable voltage without regulators, within the limits shown on Plate 1. They must also coordinate with the low-voltage ratings of supply substation step-down transformers and step-up transformers, as previously proposed in Tables VIII and IX respectively. Furthermore, they must be suitable for use in industrial or isolated plant application.

Table X gives proposed generator voltage ratings to cover these requirements.

While synchronous condensers closely resemble generators in form, they are different in operating characteristics. They require special consideration in the matter of voltage rating and their comparatively limited use makes standardization at the present time probably premature.

Summary Tabulations of Proposed Voltage Ratings

The foregoing analyses are tabulated, for convenient reference, in Table XI, which assembles the proposed voltage ratings for equipment for alternating current power systems. In this tabulation are shown voltage steps and values considered sufficient to cover the range of system conditions reasonably subject to standardization.

TABLE X

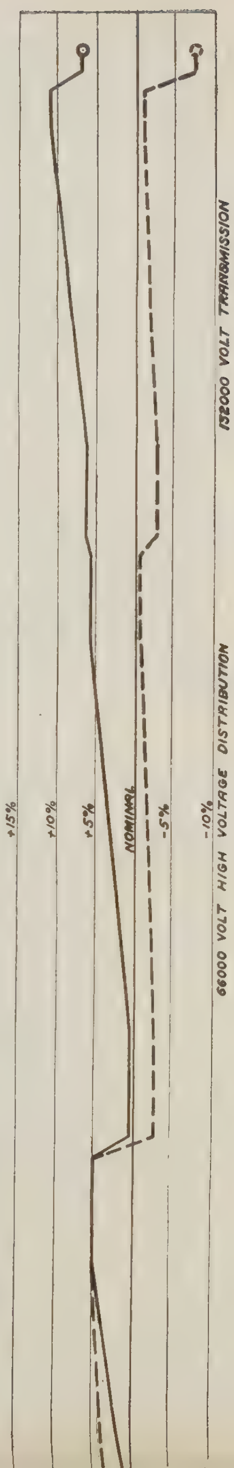
PROPOSED GENERATOR VOLTAGE RATINGS

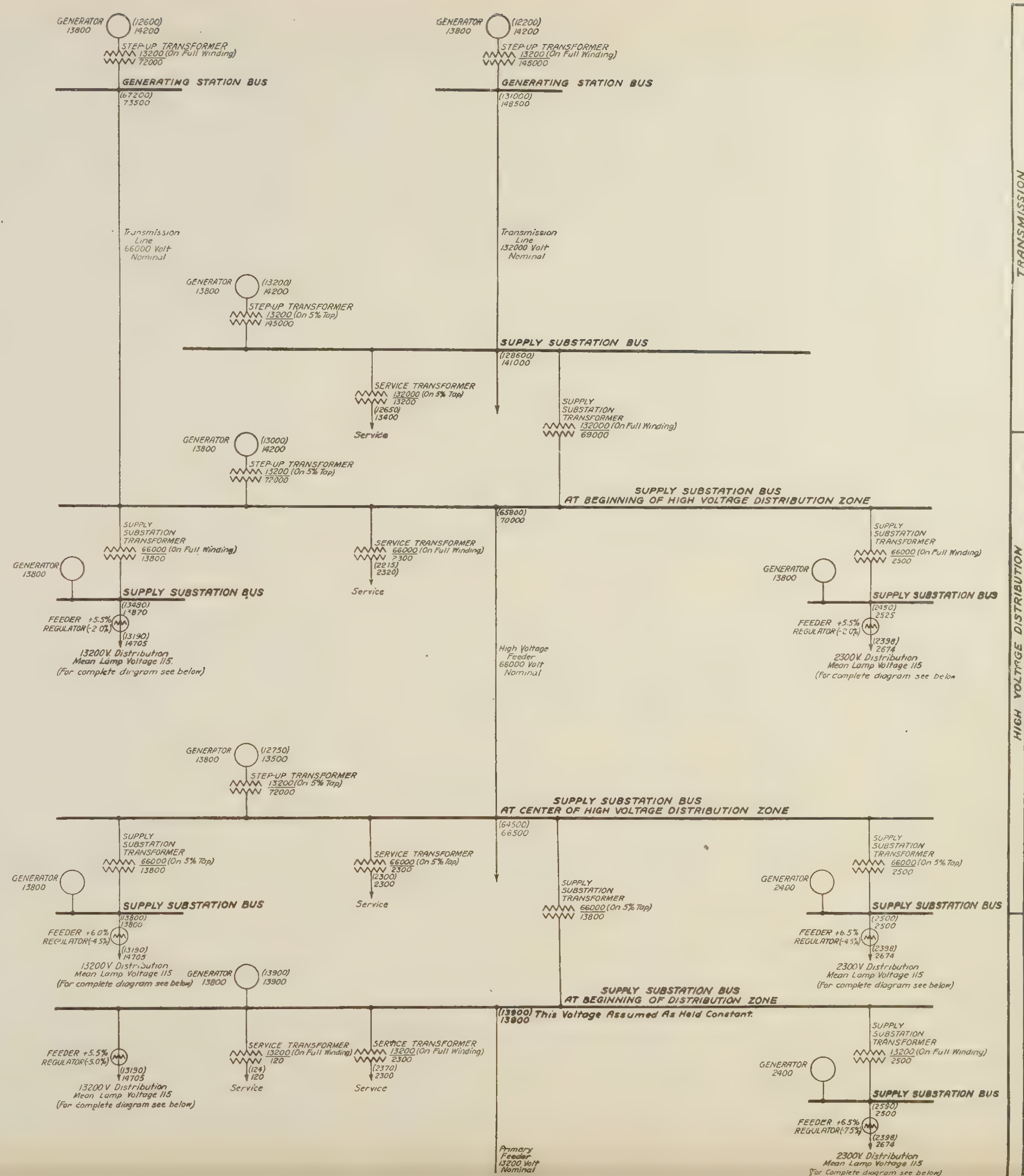
Nominal system or class voltage	Normal voltage rating*	Rated operating voltage range ± 10%
115	120	110–130
230	240	220–260
460	480	440–520
575	600	550–650
2300/4000 Y	2400/4150 Y	2200/3800 Y – 2600/4500 Y
4,600	4,800	4,400–5,200
6600/11,430 Y	6900/11,950 Y	6300/11,000 Y–7620/13,200 Y
11,000	11,500	10,500–12,500
7620/13,200 Y	8000/13,860 Y	7200/12,500 Y–8800/15,200 Y
13,200	13,800	12,500–15,200

*Rated at nominal + 5 per cent.

In reading the values in these tabulations, it should be borne in mind that ideal precision has been avoided as impracticable. It is believed that the frequent approximations employed are within reasonble limits of precision considering the many variables and inconsistencies being dealt with.

IN RELATION TO NOMINAL VOLTAGE





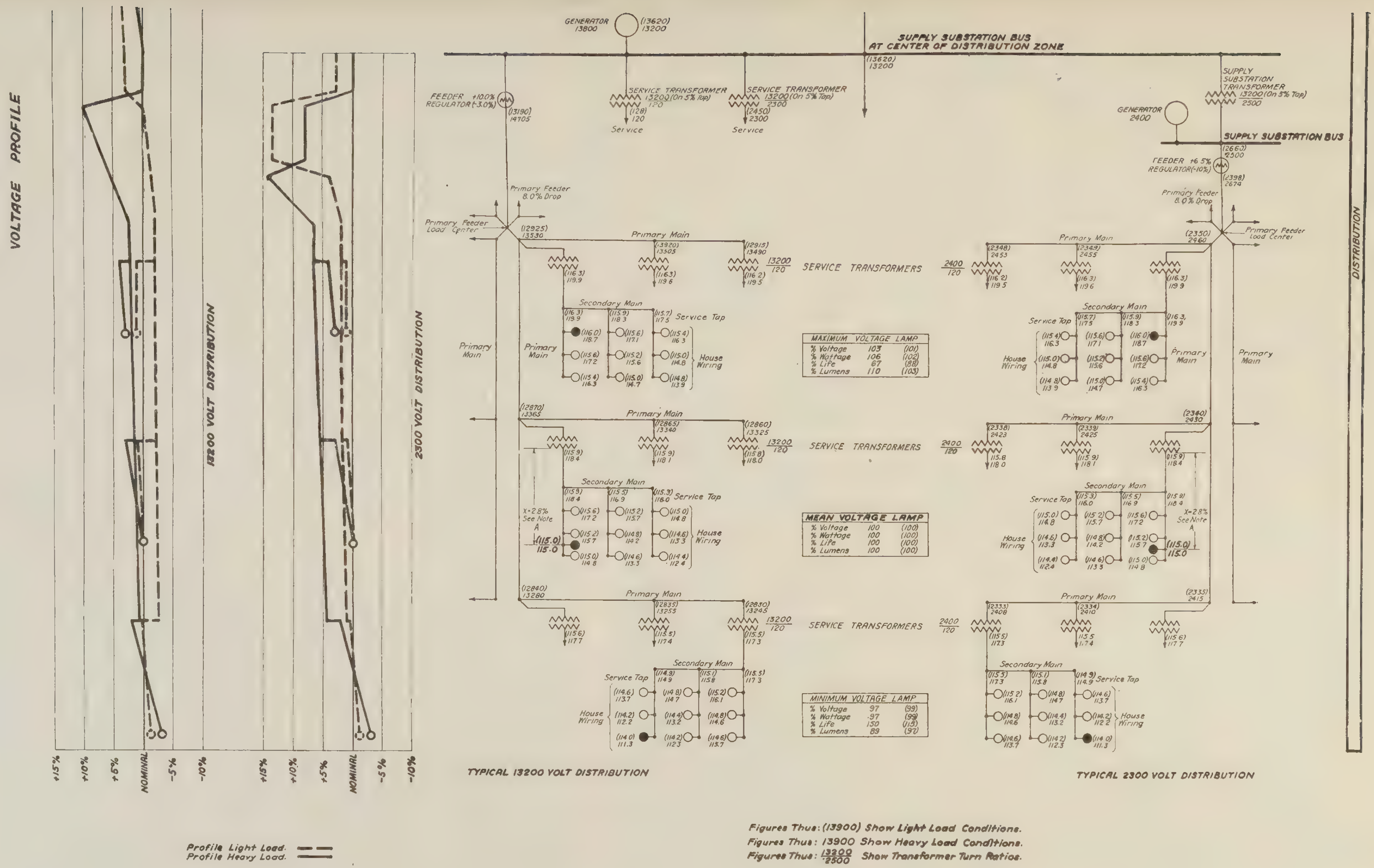


PLATE NO. 1

CHART SHOWING LIMITS OF VOLTAGE
FOR REPRESENTATIVE ALTERNATING CURRENT POWER SYSTEMS

Conclusions

1. Present voltage standards for alternating current power systems and equipment are inadequate as they do not fit the needs and practises of representative power systems. This condition is generally recognized.

2. In developing general voltage standards, it must be recognized that there are some systems, particularly those of pioneer origin, which, because of large size and individual characteristics of voltage, will doubtless continue their individual standards and move toward general standards only as the opportunity to benefit arises from time to time in the natural course of replacements and reconstruction. General voltage standards will, in effect, be schedules of preferred voltages, serving as a guide to the maximum practicable uniformity of practise.

3. In developing voltage standards, a fundamental is to establish a suitable reference level or plane for voltage designation. The present practise of a reference level established at the point of generation is not suitable. As voltage "slack" of the system is most frequently taken up at the generating stations, this method of designation gives an undue appearance of non-uniformity of voltages as between systems. At utilization, or receiving terminals, is the point of maximum inherent voltage uniformity because this is the plane where the product is delivered and service is gaged. Uniformity of product at the point of delivery is the goal of system design and operation. Therefore, the fundamental reference plane for all voltages of a given class, or "nominal system voltage," is defined as the mean voltage at utilization terminals, that is, at receiving terminals.

4. Another fundamental is to segregate the power system along functional lines into zones of different voltage levels. It is especially essential in arriving at standards for transformer voltages and ratios that the correct relation between the zones of distribution, high voltage distribution and transmission be clearly understood.

5. A third fundamental is to adhere to present standards and practises in so far as reasonably adequate. However, where experience shows that any related standards including those of the A. I. E. E. are incorrect or insufficient, any needed corrections and extensions should be made.

6. A standard lamp and appliance rating of 115 volts and a standard motor rating of 220 volts are assumed. No conclusions are drawn as to the suitability of these voltages as compared with 110, 120 or any other lamp voltage. The 115 volt rating is taken as essentially averaging present usage and recommendations of the N. E. L. A. Lamp Committee. The definite establishment of a suitable value for lamp socket voltage is basic and should constitute an initial step in developing general voltage standards.

7. In practise, there are two outstanding systems of power and lighting secondaries, the three-wire delta and the four-wire star. It is important that standard utilization equipment be fully interchangeable as between these two systems of supply.

8. A chart is given, Plate 1, which brings out voltage relations between the essential features of power systems, together with operating voltage limits, as a means of determining the spread of operating voltages that must be provided for in general voltage standards. Basic assumptions for this chart include constant voltage held at the mean lamp terminal of each distribution feeder load area, by means of feeder regulators, and constant voltage held at some other plane intermediate between utilization terminals and generating station by generator voltage variation. The chart shows a profile of voltages progressively through the systems.

9. Tabulations in Table XI summarize the proposed standard voltage ratings for systems and various types of equipment. A foot note shows the relations, in percentages, between the proposed standard system and equipment voltages. However, in the tabulated values, frequent approximations are accepted in the interest of closer adherence to present standards. The more important features of the voltage standards proposed in Table XI include:

a. The present 20:1 ratio for 2300-volt distribution transformers is retained but normal rated voltages are raised from 2300:115 to 2400:120.

b. Both ratio and normal rated voltages are changed for the distribution transformers of the 13,200 volt class.

c. Three types of transformers are established for each voltage class, each having a ratio specific to its own functional duty. These types are service step-down, supply substation step-down, and step-up.

d. Transformer ratings are such, in relation to circuit voltages, that excitation on full winding is correct when the transformer is located at the beginning or leading edge of a load area. Taps in 5 per cent steps are provided for compensating regulation across the load area.

e. The present range of 10 per cent buck and 10 per cent boost for feeder regulators is retained.

f. Normal rated voltage for generators is raised approximately 5 per cent from present standards, and a normal operating range from plus 10 per cent to minus 10 per cent is required.

g. Present normal rated motor voltage is retained, and a normal operating range from plus 10 per cent to minus 10 per cent is required.

h. General apparatus, such as feeder regulators, switching equipment and lightning arresters, are rated for normal operation at 10 per cent above nominal system voltage.

i. A 5 per cent emergency tolerance above rated maximum operating voltage for all equipment is required.

10. The proposed standard voltage ratings for all equipment above 66,000 volts are higher than present

TABLE XI

PROPOSED SYSTEM AND EQUIPMENT VOLTAGE RATINGS FOR ALTERNATING-CURRENT POWER SYSTEMS

Nominal system or class voltage*	Lamps and appliances	Motors†	Service step-down transformers		Supply sub-station step-down transformers		Step-up transformers		General apparatus	Generators
			High voltage	Low voltage	High voltage	Low voltage	Low voltage	High voltage		
115	115	110		120			115		125	120
230	230	220		240			230	250	250	240
460		440	480	480			460	500	500	480
575		550	600	600			575	625	625	600
2300/4000 Y		2200/3800 Y	2400/4150 Y	2300/4000 Y		2500/4330 Y	2300/4000 Y	2500/4330 Y	2500/4330 Y	2400/4150 Y
4,600		4,400	4,800	4,600	4,600	5,000	4,600	5,000	5,000	4,800
6600/11,430Y		6300/11,000Y	6600/11,430Y	6600/11,430Y	6600/11,430Y	6900/11,950Y	6600/11,430Y	7200/12,500Y	7500/13,000Y	6900/11,950Y
11,000		10,500	11,000	11,000	11,000	11,500	11,000	12,000	12,000	11,500
7620/13,200Y		7200/12,500Y	7620/13,200Y	7620/13,200Y	7620/13,200Y	8000/13,860Y	7620/13,200Y	8400/14,500Y	8500/15,000Y	8000/13,860Y
13,200		12,500	13,200	13,200	13,200	13,800	13,200	14,500	15,000	13,800
22,000			22,000		22,000	23,000	22,000	24,000	25,000	
33,000			33,000		33,000	34,500	33,000	36,000	37,000	
44,000			44,000		44,000	46,000	44,000	48,000	50,000	
66,000			66,000		66,000	69,000	66,000	72,000	73,000	
88,000			88,000		88,000	92,000	88,000	96,000	96,000	
110,000			110,000		110,000	115,000	110,000	120,000	120,000	
132,000			132,000		132,000	138,000	132,000	145,000	145,000	
154,000					154,000	162,000	154,000	170,000	170,000	
220,000			2400 v class and below–no taps others 2–5% full capacity taps		220,000			240,000	240,000	
					2–5% full capacity taps 1–5% reduced capacity tap			2–5% full capacity taps		

Notes: Except for service transformers up to and including 4800 volts, which are deviated to adhere to ratios now in use, the voltage ratings of all transformer primaries coincide with the value of nominal system voltage. Except for this deviation and some other approximations, to more closely coincide with existing standard ratings, the values in this table bear essentially uniform relations to values of nominal system voltage as follows:

Lamps and appliances—at nominal	Service transformers	Supply substation transformers	Step-up transformers
Motors —at nominal minus 5%	High voltage—at nominal	High voltage—at nominal	Low voltage —at nominal
General apparatus —at nominal plus 10%	Low voltage—at nominal	Low voltage —at nominal plus 5%	High voltage—at nominal plus 10%
Generators —at nominal plus 5%			

Generators and motors have a normal operating range of 10 per cent above and 10 per cent below rated voltage.

Feeder regulators have a normal operating range of 10 per cent boost and 10 per cent buck.

For transformers in general excitation is normal when the voltage impressed on the primary terminals under full rated load is sufficient to overcome regulation and maintain rated voltage on the secondary terminals.

All equipment has an emergency tolerance of 5 per cent above rated maximum operating voltage.

*As between the 6600/11,430 Y, 11,000 classes and the 7620/13,200 Y, 13,200 classes, it is recommended that so far as practicable, preference be given to the 7620/13,200 Y, 13,200 classes with the aim of eventual elimination of the 6600/11,430 Y, 11,000 classes. Possibly other eliminations may eventually be found advisable.

†Present nameplate ratings.

ratings. Because much of this equipment now in service is of necessity being operated at voltages above present ratings with reasonably satisfactory results, no extensive redesign of equipment should be imposed by these requirements. Revision of nameplate data should frequently be sufficient.

11. It is not undertaken to offer test voltage requirements for the proposed voltage standards. Doubtless, some increases and changes from present standards will be required. The standardization of test voltage practises must be deliberate. This will call not only for changes in the A. I. E. E. standardization rules but also must take into account the effects of is impulse and other transient voltage phenomena, the present knowledge of which, though advancing, limited.

EFFECTS OF CORONA DISCHARGE ON PETROLEUM

Much interest has been manifested during recent years in the use of the corona discharge during the cracking of petroleum to increase the production of gasoline, and the results of studies on this subject are given in *Bureau of Mines Technical Paper*, 375, by J. J. Jakosky.

In cracking petroleum, compounds of many different molecular weights and boiling points are present in the cracking tube. The lighter, more volatile constituents exist as gases at the cracking-tube temperature. The heavier hydrocarbons, however, exist as vapor or mist. The gases are unaffected by the corona, whereas the vapor or mist particles are precipitated against the hot walls of the cracking tube by the corona discharge, and increased cracking results. Although the increased cracking obtained when the corona was used in experiments made by the Bureau of Mines was only 5 to 8 per cent, it is possible that a higher percentage would be obtained in larger cracking tubes.

The increased cracking obtained by the use of the corona during the thermal cracking of oil appears to be due: To precipitation of the hot oil vapors or mist particles against the walls of the cracking tube; and to the decreased amount of channeling by the "electric wind" set up by the corona discharge. The effects are due largely to a purely mechanical or "precipitation" effect of the corona discharge on the droplets and particles in the field between the corona discharge wire and the walls of the tube.

A New 132,000-Volt Cable Joint

BY DONALD M. SIMONS[1]

Member, A. I. E. E.

Synopsis.—*This paper describes what is believed to be a new form of high-voltage joint. The main novelties in the joint are that the metallic union of the conductors is insulated by wrapping on a single sheet of wide, impregnated paper by machine. The ends of the cable insulation are cut into a series of steps, or a taper, and knives on the machine cut the wide sheet of paper exactly to fit the steps or taper as the wide paper is being applied, until a smooth cylinder is built up to the original diameter of cable insulation. At this moment, the knives are removed, and at each end of the wide piece of paper, strips of tinfoil which have previously been cemented to the paper appear, and these strips gradually taper inward so that as the wide paper is applied, a flaring cone of metal is formed in the body of the insulation itself. This metallic cone acts as an electrostatic screen to control the longitudinal and radial stresses. It is formed automatically without any attention on the part of the splicer in the field, and it insures that all the insulation under stress is solid laminate paper insulation of the highest quality and breakdown strength, especially in the regions where the diameter is enlarged from that of the cable sheath to that of the joint sleeve. Test results are given.*

I. The Problem

THE problem to be faced (and our description will deal in terms of single-conductor joints only), can be explained in Fig. 1, in which we have diagramatically shown two single-conductor cable ends, the conductors of which have been mechanically joined by connector No. 1. For any single-conductor joint, the first problem is to insulate the region of No. 2, in order to build up the insulation over the connector to the

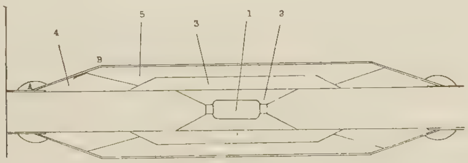


Fig. 1

diameter of the original cable. The classic methods of preparing the cable ends are to pencil (or bevel) the insulation as shown in the drawing, or to cut the surfaces into steps.

When this is done, additional insulation must be applied, and this is shown as made up of insulation No. 3, which is ordinarily applied in tape form. In place of this, tubes could be used, or a combination of tape and tubes. The metal sleeve is then passed over the insulated union, wiped to the lead at each end, and the whole is filled with compound. This is sufficient for the lower voltages.

As voltages go up, however, a new point of weakness appears, due to the concentration of stress at the point where the diameter of the outer electrode changes, under the slope $A B$ in Fig. 1. For medium voltages, it becomes necessary to bell out the lead sheath, thus reducing the stresses at this point; and in fact joint casings have been designed so as to be practically a continuation of the bell of the lead, and act, themselves, as a flaring of the lead sheath. This, however, did not remove all the difficulties. As voltages became higher, it was found that the oil or compound in the region where the lead sleeve tapers under the slope, $A B$, would be overstressed, break down, and would lead to eventual breakdown of the cable at that point, or to a surface arc from the connector No. 1.

This phenomenon is rather an interesting one, and is apparently due to the following: A liquid insulator has the characteristic that its breakdown strength decreases with thickness. Of course the breakdown voltage (in volts) will increase the thicker the layer of liquid, but its specific strength (in volts per mil) will decrease. A certain voltage is impressed between the conductor and the outer electrode, which, in the cable, is the cable sheath and in most of the joint, is the cylindrical surface of the joint sleeve. In the region, $A B$, however, there is a taper, and proceeding from A to B, more and more of the voltage is impressed on the oil or compound in the joint, and less and less on the factory-made insulation of the cable. As we proceed from A to B, however, the thickness of the oil which is under stress becomes greater and greater. From A to B, the voltage impressed on the oil becomes greater and greater, and yet its breakdown *strength* becomes less and less. A point

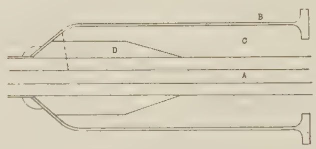


Fig. 2

is reached therefore at which the oil becomes overstressed and breaks down, and this leads to failure of the cable. The author once had a striking illustration of this principle in developing some extra-high-voltage cable terminals. The occurrence is illustrated by Fig. 2, which represents the metallic end-bell at the bottom of a terminal. A is the conductor, B is the end-bell. The end-bell was filled in the space C with oil, and of course breakdown would have taken place in the region where the taper of the end-bell approached the cable surface had we not taken some precaution to relieve the condition. This region, therefore, was wrapped with saturated fibrous material in the mass marked D.

1. Standard Underground Cable Co., Pittsburgh, Pa.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

The diameter of this wrapping could not be increased further as we desired to do because of a projecting flange at the right of B; but we hoped that we had enough there to relieve conditions. Voltage was applied, and breakdown took place as shown by the dotted line. In other words, the puncture took place through an inch of cable insulation, about 1½ in. of saturated fibrous material and about 1 in. of oil, rather than in the cable itself where we had merely the 1 in. of insulation.

The method of preventing breakdown in the oil under the tapering sleeve consists in general in filling this region with solid material, such as paper tape, V. C. tape, or impregnated candle wicking, shown as No. 4 in Fig. 1. The reason that these materials are effective is twofold; in the first place, these saturated materials have a higher S. I. C. than the liquid oil, and thus the actual voltage to be withstood is less; and secondly, the insertion of these materials in effect splits the oil up into thin layers, and we thus get away from the reduction in breakdown strength of oil in thick layers.

The question is, how to apply this principle. In one well-known and successful joint for high voltages, this was accomplished by building up a tapering surface of candle wicking at each end of the joint, the sleeve being split in the middle in a plane perpendicular to the axis of the cable. These two half-sleeves could therefore be brought up against the candle wicking, and since this is more or less flexible, it would take the shape of the tapering surface, $A\ B$. There are two objections to this method, though it has been entirely successful for the purpose for which it was designed. The objections are the time required to apply this wicking, which is considerable, and the fact that paper tape and V. C. tape have a higher breakdown strength. If it is desired to fill this region with tape insulation of paper or V. C., this also takes a long time and the tape has the disadvantage of being very difficult to apply to a given curvature, and when it is applied there is very little flexibility, and it is thus practically impossible to make

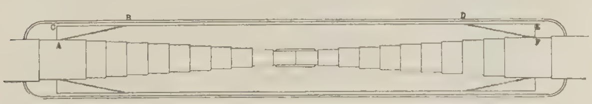


FIG. 3

the curvature at the ends fit the surface $A\ B$ which may have any desired curvature; the tapering surface of the wrapped material must therefore be metallized in some form, up to a certain distance, which again is a difficult process in the field.

It will be seen, therefore, that in a very high-voltage joint not only must the regions No. 2 and No. 3 of Fig. 1 be insulated, but steps must be taken to insulate the regions under the tapering section of the outer sleeve $A\ B$, namely the two regions No. 4. The taping by hand of the regions No. 2, No. 3, and the masses of insulation No. 4 at each end of the joint, and the application of metal to the outer surface of the latter sections, is something which requires time, the building up of large masses of insulation by hand application of thin tape being a slow process.

II. THE NEW JOINT

In the new joint which we will now describe, the insulations in No. 2, No. 3 and the two regions No. 4, as well as the metallization, is all done by applying *one sheet of insulation*, and this is applied by machine. The joint is shown in Fig. 3; the length of the joint is about 40 in., the distance from edge of sheath to edge of sheath being 38 in., and the inside diameter of the lead sleeve being

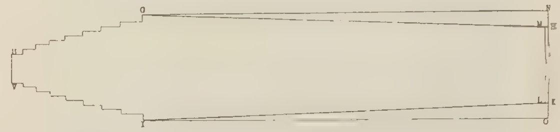


FIG. 4—LONG, UNROLLED, SINGLE SHEET OF IMPREGNATED PAPER, UGNOV, USED TO INSULATE THE JOINT OF FIG. 3 (TO VERY DIFFERENT SCALE) THE REGION TO THE LEFT HAS BEEN CUT SO AS TO FIT THE STEPS OF THE JOINT WHEN THE SHEET IS ROLLED AROUND THE JOINT. THE LINES $G\ H$ AND $I\ K$ ARE THIN STRIPS OF TINFOIL CEMENTED TO THE PAPER. THE REGION $H\ K\ L\ M$ IS COVERED WITH TINFOIL.

5 in., the length of the applied insulation $C\ E$ is 35.5 in., and its thickness $E\ F$ is 1 in.; the conductor diameter and cable insulation thickness are each about 1 in. An ordinary connector is used, and a few layers of ordinary hand-applied tape and saturated twine are applied over the beveled ends of the connector, filling up the lowest step until a smooth cylinder is obtained. From that point on up to the surface $C\ E$, a long roll of paper the full width of the joint is wrapped around, this being one continuous operation with one piece of paper shown diagramatically in Fig. 4. This long sheet of impregnated paper, which is 165 ft. long and 35½ in. wide, could be cut in advance to fit the steps, as shown in Fig. 4. Actually, we cut it by machine *as it is being applied*, thus making a very perfect fit. Referring to Fig. 4, lines $G\ H$ and $I\ K$ have been metallized (as will be described later) and also the region $H\ K\ L\ M$. It should be pointed out that Fig. 4 is quite diagramatic, as in the actual roll the ratio of length to width is about eleven times as great as in Fig. 4. When, therefore, this wide roll of paper is wrapped around the joint in its final position, it will be obvious that there will be formed in effect a solid tube of paper, containing metal cones. $A\ B$ and $D\ F$ in Fig. 3 are the metal cones imbedded in the tube, and the entire outer surface of the applied insulation $B\ D$ will also be metal-covered due to the metallized region $H\ K\ L\ M$. After the wide roll has been applied, the usual metal sleeve is applied, which may be of any diameter desired as long as it clears the line $C\ E$, and then this sleeve can be filled with compound which has low dielectric loss. It may be a hard compound if desired, so that the joint itself will require no maintenance at all, in view of the fact that

the compound is entirely shielded from stress in the joint. There is no problem of a suitable jointing compound for this joint.

As to the details of applying the wide roll of paper to the steps, and the latter part containing the metal, this is done by the machine shown mounted in place in the manhole, Fig. 5. The picture was taken actually on the laboratory wall, but the stanchions are actual stanchions used and the spacing between joints is the same as that used in the case of a Philadelphia company's 75-kv. cable. The cable ends can be seen sweated together by

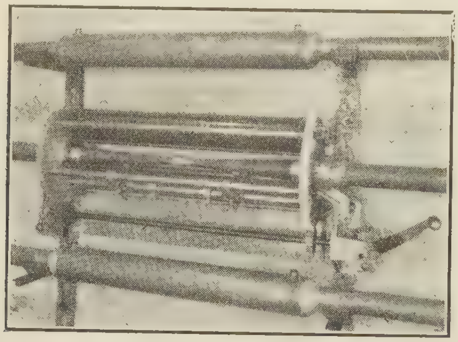


Fig. 5—Machine Ready to Wrap Paper Insulation in Steps

the connector in the middle, with the insulation cut into a series of steps. At the top of the machine is the wide roll of metallized paper, and on the bottom rods of the machine can be seen the knives for cutting the paper to fit the steps; also the two V-blocks which bear against the steps and hold the cable central in the machine against the tension of the wide paper. Fig. 6 shows the process after the steps have been filled with paper, the full-width paper being wrapped on. The strips of tapering tinfoil can be seen at each end. The roll of wide paper is mounted on the drum and the drum revolved around the cable, feeding off the wide paper as it goes. The paper passes in and out of alternate rods and is put under tension, adjustable by the number of rods used, by the course of the paper on the rods and by the location of the movable rods. Tension is also applied by pressure on the roll of paper.

The two cable ends are stripped to have enough conductor exposed at each end to permit their being jointed together by a copper tube which is sweated to both of them. The lead sheath is then removed for the required distance from each end and the necessary number of steps are cut in the cable insulation by hand, though we have planned to have this also done by the same or another machine. The jointing machine is then clamped onto the cable, and in its latest form it is supported by brackets which are held by the same vertical racks that hold the cable hangers. After the steps have been cut, saturated twine and a few layers of paper tape are applied over the connector to build it up to a smooth cylindrical surface at about the level of the lowest step. In another form, no twine nor tape is used. Perforated tinfoil is then applied to the cable insulation for a few inches at each end adjacent to the lead sheath (*i. e.*, from the sheath to slightly beyond A and F respectively), and grounded to it so as to continue, electrically, the lead sheath out to the point where the tinfoil cone will eventually be formed. The foil is perforated so as to offer an easy path for the flow of fresh compound from the joint (and its reservoir, if used) to the cable insulation.

Then the wide roll of paper is put on the machine and the two small cutters are set on one of the tie-rods directly opposite the shoulders of the first step. The paper is drawn through the cutters by hand to cut a few inches of the right width, and this is fastened to the hand-applied tape around the connector. The machine is then started, being driven either by motor or by hand. As the paper is rolled onto the cable, the two knives cut it exactly to the width of the first step, the spare paper at each side being cut off and thrown away as it accumulates. When the space between the first steps is filled up, the cutters are moved out to the shoulders of the next step and the paper is cut to fit there, and so on, until the paper has been wrapped up to the diameter of the original cable.

At this point the tinfoil strips appear on the sheet of paper (points G and I of Fig. 4), and are wrapped over the tinfoil which extends out from the lead sheath at each end. The knives are removed from the machine and the machine revolves, wrapping on the wide roll of metallized paper continuously until it forms the completed tube, the metallized portions taking care of themselves. Compound is poured onto the wide roll at each revolution. The tension is maintained steadily, and thus the final result is a mass of solid insulation, free from air and of the highest quality.

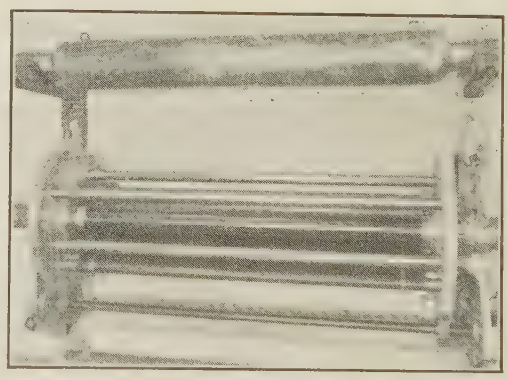


Fig. 6—Showing Cable after Steps have been Filled with Paper and Full-Width Paper Wrapped On.

The fundamental requirement of a joint is high breakdown strength, and the test results will be given later. We have, however, in this joint the fortunate combination of high breakdown strength with excellent and simple mechanical qualities. It will be seen that the whole operation is extremely simple, only one article

being applied to insulate the entire joint, and the difference in time between this method and the method of hand or machine taping is very great. For instance, in an actual field installation in a rather small manhole and with a crude and rudimentary form of machine, the entire process of applying the metallized tube, including cutting the paper to fit the steps and wrapping it on the steps, was done in a minimum time of 1 hr. and 2 min., and a maximum time of about 1 hr. and 30 min. In the field, with the final design of machine, 75-kv. joints have been insulated in as short a time as 20 min. This means that the entire insulating of the joint with the exception of one or two layers of hand-applied tape over the connector was done in these respective periods of time.

One additional feature should be emphasized: The first joints made were somewhat different. Narrow tape used to be applied to the stepped region by hand and then the metallized tube was applied from that point on, making a much longer process because of the time required for the taping. It is extremely difficult to start a sheet of paper as wide as 36 in. without entrapping air, and there is always some curvature of the cable core, which greatly increases the trouble. In fact, the only reason good results were obtained was because even though air-gaps may have existed when the wide paper was first put on, the later tension applied squeezed out the air and compound and straightened the cable. The author thinks that it would be almost impracticable, however, to attempt the use by hand of any roll of paper wider than the 3-ft. When wide paper is applied to the steps by machine, however, the paper roll is essentially a straight cylinder after its application. It will be seen, therefore, that as it is applied, the cable core is straightened automatically and gradually, as it is held central against the tension of the paper by adjustable arms on the machine. As soon as the paper has filled up any particular set of steps, that region is straight, and it is believed that the method could be used for almost any length of joint which need be considered, because the cable core will be straightened, step by step, and when the final metallized tube is to be applied, a perfectly straight cylindrical surface will be available.

III. Test Results

In developing this joint, there have been made and tested over 100 of the metallized tube joints. The first 60 joints tested were in the form of short, straight pieces of cable, there being only about 1 ft. of lead between the wipe of the joint and the temporary test terminal, this straight sample being tested in oil. From that time on, due to the difficulties with temporary terminals for the higher voltages, we have jointed two 15-ft. sections of cable, bending the cable into a U, and applying complete out-door porcelain terminals to each end.

The joint is of such a type that its breakdown strength for voltages applied for a short time will be considerably above its long-time breakdown strength. For that reason, most of our tests have been at voltages which the joint could maintain for a period of hours. It hardly seems worth while to present a tabulation of the tests on all the hundred odd joints made, as this would involve details of their construction, a great deal of which would not be of permanent value, due to changes later made in the joint. The author will therefore merely give the tests on the final design of joints, after numerous small modifications had been made in view of his earlier work. Table I gives the test results on all of the joints of the final design of cable insulated with 30/32-in.

After completing this series of tests, tests on cable insulated with 24/32-in. were started and it was found

TABLE I

EXPERIMENTAL JOINTS

SINGLE-CONDUCTOR CABLE INSULATED WITH 30/32-IN. PAPER

Test voltage	Time		Location of failure	Remarks
	Hrs.	Min.		
200 kv.	28	0	Joint	
200 kv.	23	27	Cable	
200 kv.	31	50	Cable	
200 kv.	30	8	Joint	
200 kv.	15	38	Cable	
200 kv.	8	25	Cable	
200 kv.	17	40	Cable	
200 kv.	16	28	Cable	
200 kv.	30	30	Cable	
200 kv.	48	..	..	Test discontinued
200 kv.	40	17	Cable	

TABLE II

EXPERIMENTAL JOINTS

SINGLE-CONDUCTOR CABLE INSULATED WITH 24/32-IN. PAPER

Time of test					Location of failure
200 kv.	220 kv.	242 kv.	266 kv.	293 kv.	
6 hr.	1 hr.	1 hr.	0		Terminal
6 hr.	1 hr.	41 min.			Terminal
6 hr.	1 hr.	1 hr.	41 min.		Cable & joint
6 hr.	1 hr.	1 hr.	4 min.		Terminal
6 hr.	57 min.				Joint
6 hr.	1 hr.	1 hr.	1 hr.	6 min.	Cable

that the breakdown strength of the joint was by no means as good, the failures invariably occurring in the joint rather than in the cable. After a series of experiments, it was found that with the higher stresses due to the thinner insulation, it was necessary to make the change in the field less abrupt as the diameter enlarged in the joint. The angle between the cone of tinfoil and the axis of the cable in the joint described above was 11 deg. For a cable with 24/32 in., excellent test results could be obtained if the slope was decreased to 7 deg., and Table II gives a tabulation of the tests made on cable with thin insulation and modified slope of foil. For purposes of convenience, since the tests took such long periods of time and tied up the whole laboratory, it was decided to accelerate the tests by keeping the voltage at 200,000 for 6 hrs. only, and then increasing

the voltage 10 per cent per hour. Unfortunately, it was not practicable to make a series of tests to tie together the two tables and make them directly comparable.

All voltages mentioned in this section are 60 cycles, a-c. (r. m. s.) the voltage being measured by a crest voltmeter, checked by a 50-cm. sphere-gap with the load on, and are between the conductors and lead sheath of a cable.

In addition to this experimental evidence, six of the joints have been in service since February 1926 at 75 kv. in Philadelphia, at the end of a cable line and where it connects to an overhead line about 40 mi. long, where the joints are thus exposed to all incoming voltage rises. One hundred forty of these joints have been in service also in Philadelphia since October 1926, and it is planned to use this joint on three of the experimental lines of 132-kv. cable shortly to be installed.

IV. Metal-Bearing Paper

The principle embodied in the long sheet of paper which when applied forms a cone of metal, has a wider application than merely to joints. It may be applied wherever it is desired to reduce stresses by enlarging the surface of an electrode and at the same time to insulate

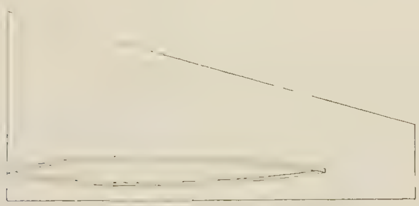


Fig. 7—Single Sheet of Impregnated Paper Bearing Two Strips of Tinfoil, Converging at Their Ends, used to Form the Terminal shown below. (The Vertical Scale is Correct; the Horizontal should be Increased about One Hundred Times)

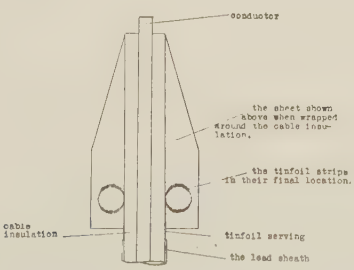


Fig. 7A—Temporary Test Terminal for a Cable

this enlarged surface. It has an obvious application in connection with terminals, either temporary terminals or permanent terminals, for cables, or in connection with bushings in general. One form we have tried out is illustrated in Fig. 7, where the lines of metallization of the paper and a cross-section of the completed terminal are shown. By applying metal to a wide roll of paper as shown in Fig. 7A, and applying it to the cable, a complete torus can be formed which, itself, is insulated positively and definitely by solid insulation of high quality. This greatly reduces the stresses at the edge of the sheath, and at the same time insulates the points to which flashover is likely to take place. There is an endless variety of shapes which can be thus formed by different methods of applying the metal to the long sheet of paper.

In regard to actual details of how the metal is applied, this can be done in various ways. A thin strip of tinfoil can be applied on one or both sides of the sheet. The paper can be metallized by a spray process on one or both sides; on one side by a spray process and having this region perforated so that the metal would go through the sheet. It also could be done in a very perfect way by metallic inlays so that the surface would be entirely smooth and there would be no building up of thickness at this point. In our actual joints, we have used throughout the very simple method of cementing a 1-mil strip of tinfoil 3/8 in. wide to one side of the paper. We have never had any trouble with the tinfoil; it stays on through impregnation, it is not bothered by the jointing machine, and it has given no difficulty. In fact, we had so little difficulty with the wide paper rolls that when we were using the wide paper over the outer part, applying it over a hand-taped stepped region, we used the same roll for as many as four test joints, reimpregnating each time. Even with this handling the foil gave us no difficulty. Obviously the foil does not make a continuous cylinder but is really in the form of a flaring spiral, whose edges simulate a cone. The only trouble we have had at all with this simple construction has been in making terminals such as that shown in Fig. 7. In this figure the layers of foil are superimposed over each other so many times that there is a building up, and some spaces are formed between paper layers, tending to form wrinkles. For a construction such as in Fig. 7, special means should be taken.

V. Conclusions

The main purpose of this paper is to describe what is believed to be a new principle in the making of cable joints and to give the experimental results obtained with a joint of given dimensions. Whether the particular tests shown in Table I are sufficient for cable for 132,000 volts, three-phase is a point which may be debatable. If it should be considered that they are not sufficiently high, better results may be obtained by making a larger joint, and this is entirely practicable. Obviously, it will be seen that the joint could be applied also to three-conductor cable with some modifications, or without modifications to the three-conductor Type H cable.

This method of making joints is applicable to the jointing of paper-insulated cable impregnated with such a thin and fluid oil that the oil would escape if the lead is cut. It is merely necessary to surround the present machine with a tank full of clear oil and, without going into all the details, remove the lead sheath of the cable under the oil, thus preventing any loss of oil. The present joint can then be made under oil, and, in fact, there are some advantages of insulating under oil in any

case, since the trapping of air is even more definitely impossible. The completed joint is then enclosed in a split oil-tight casing which can be bolted together, the machine and oil tank are removed, and finally an outer sleeve is wiped to the cable at each end around the inner sleeve and the space between them filled with oil.

The various features of the joint are covered by patents of the author, and the machine, by a joint patent held by him and F. D. Barbour, all being the property of the company with which they are both associated.

The cooperation and assistance of Mr. J. Cadwallader and Mr. W. C. Cadwallader, in the development of the joint, are gratefully acknowledged.

Voltage Standardization

BY A. HUBER-RUF[1]

Non-Member

Synopsis.—A review of the points of view which in general influence standardization of voltages and a number of proposals of certain standards are given in this paper. The discussion pertains to classes of voltages, three-phase systems, d-c. systems, and nominal voltages. A plea is made for the use of the ratio of $1/\sqrt{3}$ for working voltages.

I. General

THE standardization of voltages forms the most important basis for the economic manufacture of electrical machinery and apparatus, and for the installation of electrical plants.

In recognition of this fact, the electrotechnical bodies in various countries have drawn up standards, and the International Electrotechnical Commission has now undertaken the task of bringing into line the various standards set up in different countries so as to provide a better international basis for the manufacture of electrical plants, and to facilitate the exchange of energy between neighboring countries.

This report contains only a brief review of the points of view which, generally speaking, influenced the standardization of voltages, and gives a short summary of the results of this standardization.

A few remarks are made at the end concerning American practise so far as the writer of this report was able to obtain information on it on the occasion of the I. E. C. Conference in New York in April 1926 and from various other sources.

The following were the principal deciding factors in the selection of standard voltages:

1. Consideration of the voltages most used in the countries concerned,

2. Consideration of the voltages standardized in neighboring countries,

3. The fixing of as few voltages as possible, at suitable intervals.

The consideration of the three points mentioned presented some difficulties and the solutions proposed are consequently the results of compromise.

Exhaustive inquiries were made in various countries in order to settle the first question, concerning the extent to which the different voltages were employed. The importance of the various voltages, considered from the point of view of connected load in kilowatts, and the extent of the transmission plant was recorded graphically.

Fig. 1 gives an example of such a graphic record drawn up for Switzerland in 1919 for lighting and power systems.

Tables and graphical records were also made for the settlement of the second question, concerning standardized voltages in different countries.

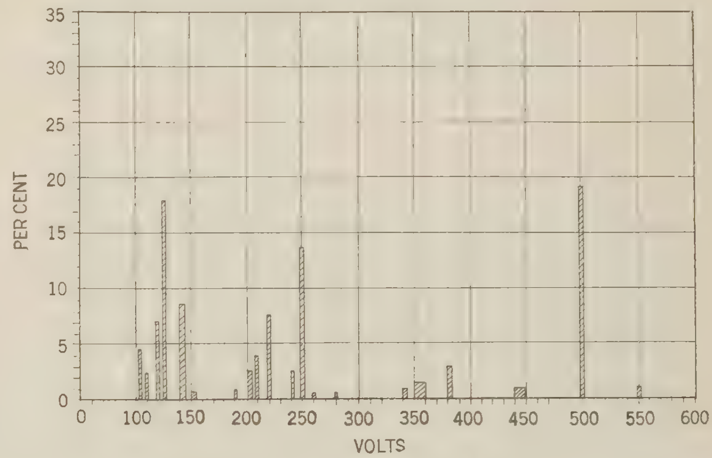


FIG. 1—FREQUENCY OF OCCURRENCE OF NOMINAL VOLTAGES IN LIGHTING AND POWER SYSTEMS IN SWITZERLAND (1919). THE VERTICAL LINES OR AREAS REPRESENT THE LOADS CONNECTED TO THE CORRESPONDING VOLTAGES IN PER CENT OF THE TOTAL LOAD CONNECTED TO THE SYSTEM IN QUESTION

Fig. 2 contains such a record for three-phase voltages in various countries.

The third point, "The fixing of as few voltages as possible, at suitable intervals," offered special difficulties.

It was generally recognized to be advantageous for three-phase working that the voltages should bear to one another the ratio $1:\sqrt{3}$ on account of the possibility

1. Brown Boveri Company, Switzerland.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

of changing over the windings of machines and transformers from star to delta, and the increased possibility of utilization of material resulting therefrom.

Voltages have hitherto been standardized, however, mainly with the ratio 1:2, having regard, obviously, to the series-parallel connection of d-c. or single-phase a-c. machinery.

Series-parallel connection is also possible with three-phase windings but it presents considerable disadvantages as compared with delta-star connection. This point will be brought forward again later on as it is of great importance.

II. Classes of Voltages

In this report, distinction will be made between the following classes:

Class A, up to 99 volts,
Class B, 100 to 990 volts,
Class C, 1000 to 29,000 volts,
Class D, 30,000 to 100,000 volts,
Class E, over 100,000 volts.

Further particulars concerning the standardization of d-c. and three-phase voltages are given in the following, three-phase voltages being considered first as being more important as regards generation, distribution, and utilization of electrical energy.

III. Standard for Three-Phase Systems

Class A, up to 99 Volts. This class is of importance mainly for direct current and single-phase alternating current. There are already several standards existing in various countries. Hitherto the voltages falling within this class have not been dealt with by the I. E. C. They are of chief importance for the lighting of electric vehicles, etc., for telegraphy, and for electro-therapeutics.

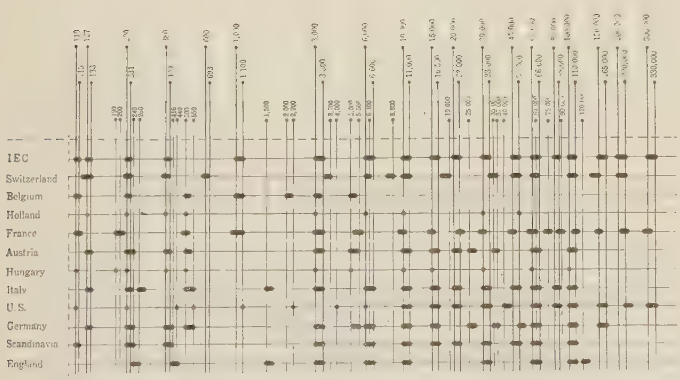


Fig. 2—Voltages for Three-Phase Systems. Comparison of the Standards of Various Countries

Class B, 100 Volts to 990 Volts. This is the most important class as it comprises house installations and the majority of apparatus utilizing electrical energy.

One hundred ten volts was used at first for lighting and power. When the load and the length of lines increased, the distribution voltage was raised successively and separate mains for higher voltages were frequently installed in towns for supplying electricity for power purpose. In many places this has led to complicated installations.

It has now been the practise for many years to supply energy for lighting, power, and heating, as far as possible from the same mains. Experience has shown that in this case the three-phase, four-wire system presents the most economic solution. For lighting and for small heating apparatus, about 220 volts between the phase leads and neutral is used while about 380 volts between star-connected phase leads is used for motors and larger apparatus.

Higher voltages are also suitable for power purposes, but lighting voltages much above 220 volts, which would result from the use of higher voltages for power in the same mains, are not to be recommended at present owing to the impossibility of manufacturing satisfactory lamps.

Two hundred twenty volts was also selected for three-phase because this voltage was widely used in d-c. and single-phase a-c. systems; lamps and small apparatus for domestic and industrial purposes can therefore be used for all systems, an important feature for the economic manufacture and use of apparatus of this nature.

In addition to 220–380 volts, it is advantageous, from the point of view of existing plants and special conditions, to fix two other standard voltages in Class B, one above and one below in the ratio $1:\sqrt{3}$, namely, about 127 and 660 volts. By changing over star-delta, motors and transformers can thus be used for two adjacent voltages. See Fig. 3.

The ratio 1:2 between adjacent voltages would be very desirable for direct current. Series-parallel connection for three-phase motors, however, necessitates subdivision of the windings and bringing *nine leads* out of the stator frame when the ratio 1:2 is used, whereas for changing over from star to delta, only the *six ends* of the three phases need be led out.

In European practise, motors are provided with terminal plates having six terminals corresponding to the beginnings and ends of the three phases. The change from delta to star can then be effected simply by changing over three connecting links on the outside terminal plate. There usually is not sufficient space on small and medium sized motors to accommodate nine terminals for changing over from series to parallel.

Changing over transformer windings from star to delta is also simpler than using series-parallel connections. Furthermore, three-phase motors and transformers are more reliable in operation when arranged for star-delta connection than when arranged for series-parallel connections, since the latter requires more internal connections and therefore offers more sources of trouble.

The International Electrotechnical Commission took these considerations into account by deciding on the standard voltages for Group II. The voltages stand-

ardized are 127–220–380 volts and also 110–190 volts. In addition to these 115–200 volts and 133–230–400 volts were designated as standard, but with the reservation that each country must decide upon either one or the other series. The most recommendable voltages, however, are 220–380 (Three-phase, four-wire system with 220 volts between phases and neutral for light and 380 volts between phases for power).

Class C, 1000 Volts to 29,000 Volts. From the comparison of the standards of various countries, (Fig. 2,) it is evident that the I. E. C. voltages, *viz.*, 3000, 6000, 10,000, 15,000, and 20,000 volts are standard in most countries, or at all events there are only relatively slight variations.

In the connection it should be noted that in each individual distribution system, generally only one or another of these voltages is used.

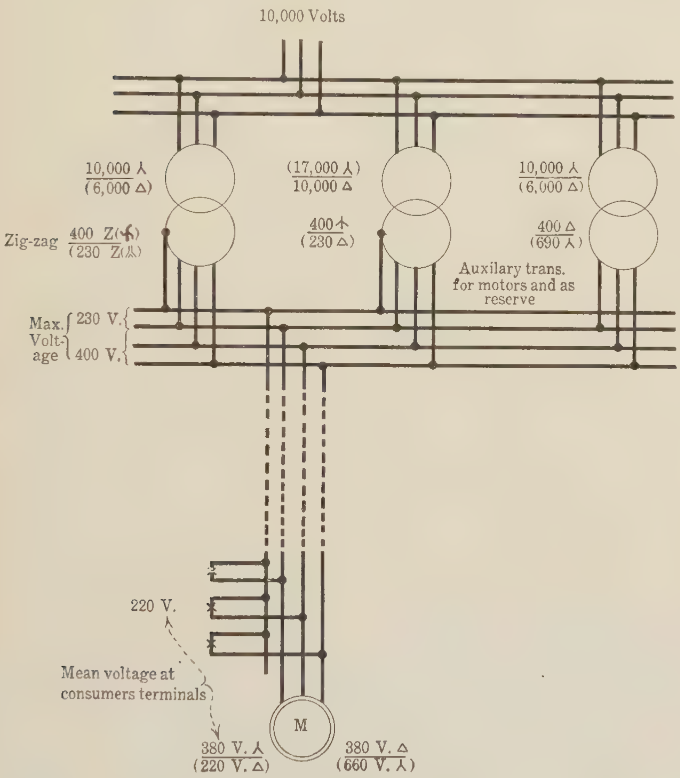


Fig. 3—Three-Phase Distribution for Light and Power Mean Voltage at Consumers' Terminals. (Primary Terminals of Transformers)

To bring about a subsequent reduction in the comparatively large number of steps, the voltages in heavy type were specified as preferred standard voltages.

The following proposal, which had a similar object in view, was submitted to the I. E. C. by the Swiss Committee. In order to allow an increased range of application for this class of voltages by means of the star-delta change-over on machines and transformers, and at the same time to omit one step, it was proposed to alter the voltages 3000 and 6000 to some small extent and to bring together in one step the voltages 15,000–20,000. The resulting series was 3300, 5800, 10,000 and 17,300. Unfortunately this proposal (Appendix I) was not accepted at the conference in New York. The change would not have altered the size of machines, transformers, apparatus, and types of insulators, but the windings would have had to be altered slightly. The result of the alterations would have been a considerable simplification, however, and for this reason the question will be brought up again when it comes to standardizing windings and transformer taps.

Class D, 30,000 Volts to 100,000 Volts. The voltages of this class accepted as standard by the I. E. C. were the widely used values of 30,000, 45,000, 60,000, 80,000, and 100,000 volts, those in heavy type being preferred voltages.

The Swiss Committee also placed a proposal for this class (Appendix I) before the I. E. C., suggesting that the pressures of 30,000 and 60,000 volts should be changed to 33,000 and 58,000 volts so as to ensure the possibility of star-delta connection between these pressures and between 58,000 and 100,000 volts.

Considerations of the present state of affairs and doubts as to the utility of the proposal regarding these high voltages led to this proposal also being rejected by the I. E. C.

It was asserted in particular that it would not be economical to use, for example, transformers insulated for 100,000 volts in 60,000-volt installations. This was not intended for general practise, however. It should be made possible, however, for reserve transformers or even normal transformers, to be used in emergency cases in systems of the next lower voltage by changing over from star to delta.

In this connection an actual case should be mentioned which came to the knowledge of the writer of this report, after the Conference in New York. In the Queenston Power Station at Niagara, transformer units each comprising three single-phase transformers with a total capacity of about 50,000 kw. are changed over from 120,000 volts to about 60,000 volts with disconnecting switches, by means of the star-delta connection. The correct voltage is obtained by regulation on the generators. Although the voltages are approximately in the ratio 1:2, use was not made of the series-parallel connection of the windings, but of star-delta change-over instead; this in spite of the disadvantage that the voltage of the generators has to be regulated to a considerable extent.

Transformers of Class D usually have low-voltage windings belonging to Class C. If the change-over could be effected in both classes, the advantages, of course, would be correspondingly greater, as indicated in Fig. 3.

Class E, Over 100,000 Volts. The I. E. C. has decided on 150,000, 200,000 and 300,000 volts as standard voltages above 100,000 volts.

These voltages bear to each other and to 100,000 volts the ratio 1:2. It was assumed that it would be general practise in such plants to use a combination of three

single-phase transformers instead of one three-core transformer, so that if necessary, series-parallel connection would be used with some advantage. Three-core transformers are also designed, however, for pressures over 100,000 volts. The example of the Queenston Plant shows that for groups of three single-phase transformers, also, the star-delta change-over connection is preferable to series-parallel connection, particularly so because it is frequently necessary to change over relatively quickly outside the transformer, and for this purpose single-phase transformers must each be provided with four high-voltage terminals for series-parallel connection.

It is often the practise in high-voltage and extra high-voltage plants to use lower transmission voltages when starting operation and during the first period of operation. This is done on the one hand to test the plant more carefully and on the other hand because the load demand at first usually is not equal to its subsequent maximum.

These considerations, too, indicate that the possibility of a simple change-over to a lower voltage is desirable with transformers, and that wherever possible the lower voltage should also be a standard voltage.

IV. Standard Voltages for D-C. Systems

Class A, Up to 99 Volts. The fields of application are the same as mentioned in paragraph III A. The d-c. voltages also of class A have not yet been dealt with by the I. E. C.

Class B, 100 Volts to 1000 Volts. The more extensive d-c. systems are to be found in towns. New d-c. systems, however, are no longer installed on a larger scale for lighting and power as the economic advantages of three-phase, four-wire distribution are very considerable. A certain relationship, *i. e.*, common voltages for d-c. and three-phase systems, is very advantageous, however.

It might have been possible to obtain this relationship at 110 volts, but this was considered too low for lighting and domestic apparatus generally on account of the large cross-sections of conductor necessary. The fact that 110-volt lamps are more reliable than, for example, lamps for 220 volts, was not of such importance because the manufacture of lamps will be improved. The pressure derived from 110 volts between phase leads and neutral, *i. e.*, 190 volts for power mains, is, generally speaking, also too low.

In addition to 100 and 220 volts, 440 volts is also widely used in d-c. systems, and various combinations of 110 and 220 volts, namely 2×110, 4×110, and 2×220 volts, were accepted as standards by the I. E. C.

The I. E. C. has also designated as standard the pressures 115, 230, and 460 volts, but with the reservation that each country must decide upon either one or another series.

Higher voltages in this class and voltages in the next classes are used principally for electric traction which for the time being is not being taken into consideration.

V. Nominal Voltages, Voltages at Consumers' Terminals, Maximum Voltages and Test Voltages

According to the standards in some countries the mean voltages at consumers' terminals are taken as nominal voltages for class B, while for classes C and D the maximum voltages at the generators and secondary terminals of transformers were fixed as nominal voltages. In favor of the second ruling, it is maintained that the calculation of the test voltage for a plant should be based on the nominal voltage and that the highest voltage normally occurring should be used as a basis for the calculation of the test voltage.

This consideration is correct as far as it goes. It is also easily possible, however, to base the calculation of the test voltage on the mean nominal voltage at con-consumers' terminals, provided allowance is made for the difference between this and the maximum allowable voltage in the system in question. According to various standards and also according to the I. E. C., this difference amounts to about 10 per cent for class C and the higher classes of voltage.

The question as to which voltage in a plant is to be taken as the nominal voltage is thus of secondary importance as far as the reliability of material is concerned. The most important point is that the same voltage shall be used throughout as a basis, and that the same safety factors and factors for calculation of test voltage be employed by the different countries.

The opinion in Switzerland is prevailing that the formula given by the I. E. C. in Publication 34 for medium sized machines and transformers, *viz.*, test voltage $= 2\,E + 1000$, is sufficient for testing the insulation of windings, *i. e.*, when a solid or liquid insulation material is in question, thus including also large machines and transformers. A test voltage of $2\,E + 10{,}000$ is proposed for insulators where air is the dielectric medium. In other countries there is a question of increasing the factors to some extent. As this does not directly affect the standardization of voltages, further details will not be dealt with here.

The fixing of the *mean voltage at consumers' terminals* as nominal voltage was very strongly advocated in France on the grounds that this voltage usually figures in contracts for the supply of electricity and should therefore be considered as the nominal voltage. The I. E. C. accepted this proposal. This solution has the advantage that the nominal voltage of all classes is referred to the same point in the system, *i. e.*, to the mean voltages at the consumers' terminals (lamps, motors and primary terminals of transformers).

This point is not made sufficiently clear in various regulations, including those of the Electric Power Club. The next section of the report will deal with this subject more fully. The decisions of the I. E. C. relative to the question and the table of accepted nominal voltages are given in Appendixes II and IIa.

Figs. 3 and 4 show diagrams of connections for three-phase installations. These give the maximum voltages at the generators and secondary terminals of transformers, and also the mean nominal voltages at the lamps, motors and primary terminals of transformers, for net-work of nominally 220–380, 10,000 and 100,000 volts.

Fig. 3 also indicates various possibilities of changing over on the primary and secondary sides of transformers and motors.

VI. Remarks on American Practise

The relations between Europe and America in the field of electrical engineering have always been relatively close. In the conferences of the I. E. C., and when drawing up standards for various countries in Europe, endeavors have been made to give due regard to American practise, also.

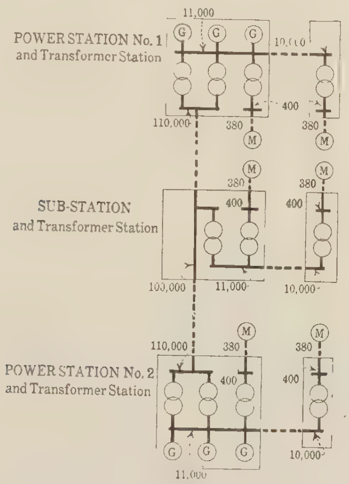


Fig. 4—Distribution of Voltage. Limiting Values

The following case is assumed: Two power stations operating in parallel. Generators for 11,000 volts at full load, one in each station connected to 11,000/400-volt transformer for direct distribution in the immediate vicinity; 380 volts at motor. One 11,000-volt outgoing feeder to a transformer station for supplying another district; as before, transformation ratio 11,000/400 volts and 380 volts at motor.

There are also 11,000/110,000-volt transformers in each power station supplying a substation situated about half way between them, containing 100,000/11,000-volt transformers. Energy is distributed from the substation by means of 11,000/400-volt transformers. There is also an 11,000-volt outgoing feeder for supplying a transformer station at 10,000 volts in another district. This station also transforms down from 10,000 to 400 volts for a pressure of 380 volts at motor terminals (220 volts for lightning).

The Conference in New York in April, 1926 made possible a still closer cooperation between electrical engineers in America and Europe. Earlier discussions of the I. E. C. led to the opinion that American practise regarding standard voltages shows many points of similarity to European practise. In particular, the view was held that the American standard voltages, 6600, 11,000, 22,000, 33,000, 66,000, 88,000, 110,000, and 220,000, represented the maximum voltages of the systems in question, in which 6000, 10,000, 20,000, 30,000, 60,000, 100,000 and 200,000 respectively were the mean voltages at the end of the lines, *i. e.*, at the primary terminals of the step-down transformers. It was thus supposed that the American standards agreed with the European standards, as these give as nominal voltages the same values, 6000, 10,000, 20,000, 30,000, 60,000, 80,000, 100,000 and 200,000 volts, at the consumers' terminals and at the primary terminals of transformers, these values being about 10 per cent lower than the maximal voltages. The difference of about 10 per cent between the mean nominal voltages and the maximum voltages on one and the same system was accepted as I. E. C. standard.

The view that the voltages, 6600 volts, etc., are an American standard maximum is confirmed apparently by some standards of the Electric Power Club. On page 185, for example, taps of five per cent (6270 volts) and 10 per cent (5940 volts) are quoted for 6600-volt transformers. This would obviously indicate that at the consumers' end of a line, *i. e.*, in this case at the primary terminals of the transformer, the pressure is about 5940 or 6000 volts according to the load and the length of the line. This would correspond exactly to the nominal voltage or mean voltage at consumers' terminals accepted by the I. E. C.

The low-tension voltage quoted by the Electric Power Club as standard for 6600-volt transformers is 220–440 volts. This appears not to agree with other standards defined by the Electric Power Club. On page 129, 220–440 volts are quoted, amongst others, as standards for motors. Lamps and other apparatus are also constructed for 220 volts. Such apparatus, however, is very seldom installed immediately near the transformer terminals, but some length of network is usually necessary, involving a voltage drop which must be taken into consideration. This drop for low voltage is assumed to be about five per cent on an average. The mean voltage at the secondary terminals of the transformer should therefore be raised by this amount. Thus, if motors are wound for 220–440 volts, the voltage at the secondary terminals of the transformers should be about 230–460 at full load. With this correction, the transformers would correspond to the I. E. C. standards. The latter standards do not yet contain data for increased voltages at the transformer secondary terminals for the low voltages but this question is to be settled at the next meeting.

The above remarks concerning the transformers for 6600 volts as defined by the Electric Power Club apply similarly to the transformers of other standard voltages, *i. e.*, 11,000 volts, 22,000 volts, etc.

VII. Concluding Remarks

The foregoing report emphasizes intentionally the importance of the *three-phase current* for the distribution of energy for lighting and power, as the standardization of voltage is influenced thereby.

The report also deals very fully with the question of star-delta change-over of machine and transformer windings, for the following reasons: In standardizing, great importance is rightly attached to voltages used hitherto. In addition to this, there is, however, the not less important question of adapting the standardized voltages to three-phase current, to be con-

sidered. If it is asserted that the change-over from star to delta is relatively seldom used at medium and high voltages and that it will not therefore be of great importance, it should be remarked that up until now it was not possible to make use of this change-over with many of the voltage used hitherto, as the resulting voltages are not standard. It is nevertheless frequently pointed out that the pressures 3, 6, 10 kv., and 30, 60, 100 kv. allow the change-over to a large extent. The approximation, however, especially at 3–6 and 30–60 kv., is not sufficiently close. Swiss electrical engineers are of the opinion that a closer agreement between the values would be of great advantage to manufacturers and electric supply companies.

These remarks should in no way lessen the importance of the fact that the I. E. C. has succeeded in fixing standard voltages to which all concerned are agreed. These voltages also form a basis for considerable simplification, as compared with conditions hitherto prevailing.

Appendix I

INTERNATIONAL ELECTROTECHNICAL COMMISSION

———

PROPOSALS OF THE SWISS COMMITTEE REGARDING STANDARD VOLTAGES FOR THREE-PHASE CURRENTS

A. Proposal. At the meeting held on the 21st April, 1925, at the Hague, it was decided to submit to the National Committees the following proposal of the Swiss delegate, M. A. Huber-Ruf, in regard to the standardization of high pressures. This proposal was inadvertently omitted from the Minutes R. M. 22.

The three-phase pressures proposed by the Advisory Committee on Standard Pressures, which bear to each other an approximate ratio of $1:\sqrt{3}$, should be modified and fixed as shown below, in order to make star-delta interconnection possible.

Two series should be formed, one starting from 10,000 volts and the other from 100,000 volts, as follows:

1st series..... 3300 5800 10000 17300

2nd series.... 33000 58000 100000

It is recommended that the pressures of 3000, 6000 and 15,000–20000 volts should be replaced by the pressures of the first series above, and pressures of 30,000 and 60,000 volts by those of the second series, in all new installations or when important additions or modifications are made to existing installations.

B. Explanation of the Reasons for the Proposal. The rational manufacture in series of three-phase machines and transformers requires above all the use of standard pressures interrelated by the ratio $1:\sqrt{3}$. This scale is the only one in which a standard pressure is obtained when the change from star coupling to delta coupling, or vice versa, is made.

The foregoing proposal satisfies this requirement for the *most commonly used* pressures and will also make it possible to establish in the future a standard series of high three-phase pressures as rational as that which has been fixed for low three-phase pressures on the basis of the ratio $1:\sqrt{3}$.

Appendix II

STANDARD VOLTAGES, R. M. 42

A. DECISIONS OF THE NEW YORK CONFERENCE OF I. E. C., 1926

1. Voltages, Class A.

TABLE I

Series	Voltage at Consumers' Terminals		
	Direct Current	Alternating Current	
		Single-phase	Three-phase
I	1 × 110 2 × 110 4 × 110 1 × 220 2 × 220 1 × 440	1 × 110 2 × 110 1 × 220	110 127 220
II	1 × 115 2 × 115 4 × 115 1 × 230 2 × 230 1 × 460	1 × 115 2 × 115 1 × 230	115 133 230

a. Each country must decide either on Series I or Series II.

b. The values given for three-phase are the voltages between line and neutral. The voltages between phase leads corresponding to the given values between line and neutral must also be considered as standard values, *e. g.*, 380 volts. (This note will be added to the table drawn up by the I. E. C.)

2. Voltages, Class B.

a. THREE-PHASE VOLTAGES

TABLE II

Nominal I. E. C. Voltages Mean Value at Consumers' Terminals	Maximum Voltages
1,000	1,100
3,000	3,300
6,000	**6,600**
10,000	11,000
15,000	**16,500**
20,000	22,000
30,000	**33,000**
45,000	50,000
60,000	**66,000**
80,000	88,000
100,000	**110,000**
150,000	165,000
200,000	**220,000**
300,000	330,000

b. Definition of "nominal high voltage:" The nominal high voltage shall be the mean voltage at the consumers' terminals and shall be called nominal I. E. C. voltage of the network of that voltage range.

c. The maximum voltages at the generators and secondary terminals of transformers shall be considered to be about 10 per cent higher than the mean voltages at the consumers' terminals. The values are included in the above table.

d. The maximum and minimum values of the voltages according to paragraph I, and the variations occurring under working conditions, should be considered at a later date.

e. Preferred nominal voltages. The voltages which are in heavy type are preferred high voltages.

Transmission Line Voltage Surges

BY J. H. COX*

Associate, A. I. E. E.

***Synopsis.**—Records of the transients actually occurring on transmission lines of widely varying characteristics have been obtained recently with the klydonograph.*

1. These records substantiate many of the theories of transients on lines.

2. They indicate the incorrectness or incompleteness of some of hese theories.

3. They suggested modifications or extensions of these latter theories.

This paper is a coordination of those theories which agree with test data obtained up to the present time. Since the results of the klydonograph surge investigations are presented in a companion paper, only the data required to make this paper complete in itself are included.

Introduction

THERE has been a great deal of discussion regarding the high-voltage transients which appear on transmission systems. Switching operations and lightning are the most important causes of these transients. Due to their extremely short duration, there was, until recently, no instrument available for obtaining definite information regarding their characteristics. Their nature had been deduced from operating experiences such as flashovers and apparatus failures. Although electric circuit theory became quite well known, different assumptions in the premises led to different conclusions—hence the divergence of opinion.

Since the recent advent of the klydonograph and the cathode-ray oscillograph, field data, secured under a wide variety of conditions, have been obtained, with the former in America and with the latter in Europe. These data do much toward clarifying the situation. In this paper an attempt is made to coordinate the author's experiences and certain theories of surges, both switching and lightning, which are substantiated by field results.

I. Switching

Ideal Case. The well known theory of traveling waves will be briefly reviewed. For simplicity the ideal case will be considered first. This is the case where a single line is switched from a limitless source, and the potential is applied or removed instantly. At the instant of such an operation, a sheer-front voltage wave, equal to the applied voltage, proceeds out along the line. It is accompanied by a current wave, equal in magnitude to the voltage divided by the surge impedance. These waves, when they reach a terminal, reflect with full magnitude with the same or opposite sign, according to whether the line is open or short-circuited, and according to whether the voltage or current wave is considered. The reflected wave will then add to, or subtract from, the initial wave. The maximum voltage possible from this effect on a homogeneous line is twice the applied voltage. This is shown in Fig. 1. A transformer at the end of a line, due to its high open-circuit impedance, presents the same condition to a surge upon its first impression, as an open line.

In the case where the end of the line is neither open nor closed, but joins a line of different surge impedance, there is a reflected wave and a transmitted wave. Where E is the voltage of the initial wave, Z_1 the surge

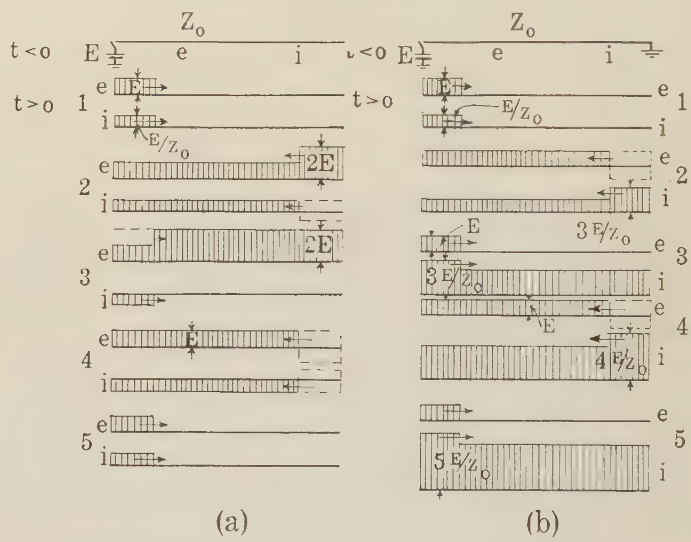


FIG. 1—TRAVELING WAVES ON TRANSMISSION LINE
(a) End open (b) End short-circuited

impedance of the first line, and Z_2 that of the second line, the reflected wave is equal to $\dfrac{Z_2 - Z_1}{Z_1 + Z_2}\, E$,

and the transmitted wave is equal to $\dfrac{2\,Z_2}{Z_1 + Z_2}\, E$.

This effect is shown in Fig. 2. The usual open air line has a surge impedance of the order of 550 ohms, and a cable 50 ohms. Taking the case of a composite line, it is seen that, if a switch is closed on the cable section, there will be a reflection where the wave enters the open wire part, and the transmitted wave will have a magnitude of nearly $2\,E$. Then if the open wire line is open ended, or ends with a transformer, the wave will reflect giving a total potential of nearly $4\,E$. Obviously, if a line divides into two or more branches, the branches

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Presented at the A. I. E. E. Winter Convention, New York, N. Y., February 7-11, 1927.

present to the line the same effect as a line of lower surge impedance.

Practical Case. In the practical case of alternating-current switching, the point of the applied wave at which contact is made, is a more or less haphazard affair. There is a tendency to arc over at the crest of the wave, especially at the higher voltages now used. However, with the usual closing speed of contacts, and

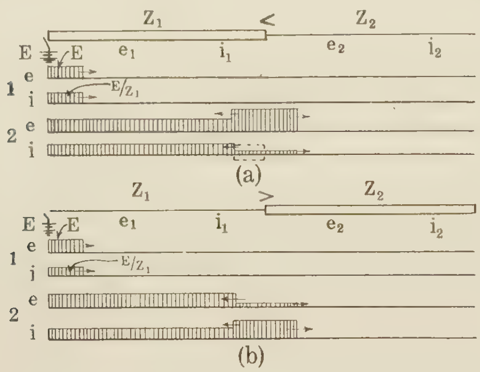


Fig. 2—Reflections at the Junction Point in a Composite Line

(a) Passing from cable to open wire
(b) Passing from open wire to cable

the breakdown strength of oil, this tendency is not the controlling factor. Thus the traveling wave, initiated by a switch closure, will not always have a magnitude as great as the normal crest voltage. Of course, the reflections are governed by the original wave.

It must be remembered that the above discussion applies to the ideal case. Although the application of voltage by a switch closure in practise is a rather abrupt phenomena, it is not instantaneous. The voltage on the part being energized rises from zero to the

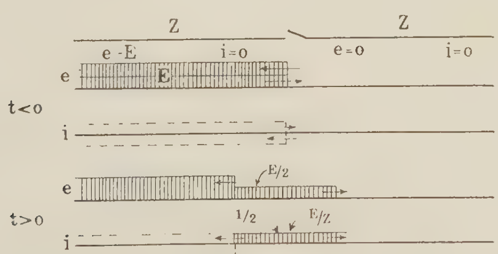


Fig. 3—A Line Energized from a Similar Line

full value in a time of the order of 0.1 microsecond to a few microseconds; that is, the front of the wave sent out extends over from 100 ft. to a mile of line at the start. There are, however, two factors entering into the practical case, each of which tends to lengthen the wave fronts of surges and to lessen the voltages obtained.

Limitation of Source. In practise, when a line is switched, it is not done in connection with an infinite power source. The nearest approach to this condition is closing a single line on a high-capacity bus; that is, a bus which has many other connected lines. When a line is closed to a similar line, the wave sent out is equal to $\frac{1}{2} E$, as shown in Fig. 3. Here the maximum voltage with reflection will be E. When a line is closed on a bus having more than one other line energized, the wave sent out is greater than $\frac{1}{2} E$, and approaches E as a limit. Another common case is where a line is energized from a transformer. Whenever there is a voltage wave, there must be an accompanying current wave equal to E divided by the surge impedance Z_0. It is impossible, however, for current to build up instantly in a transformer. The rate of rise will be limited by the leakage inductance of the transformer, and the wave front will be sloping. If the front is more than twice as long as the length of the line, there can not be a complete reflection, since, after the foot of the wave has traveled to the distant end and back, it will disturb the conditions at the terminal point considered.

Fig. 4 shows the approximate circuit of a line being switched from the high-tension side of a transformer. The potential of the line is determined by the relation

$$e = i\, Z_0 \tag{1}$$

The relationship between the currents and voltages in the circuit is

$$R\, i + L \frac{d\, i}{d\, t} + e = E$$

or upon substituting,

$$\frac{d\, i}{d\, t} + \frac{R + Z_0}{L}\, i = \frac{E}{L} \tag{2}$$

where E is the voltage on the low-tension side of the

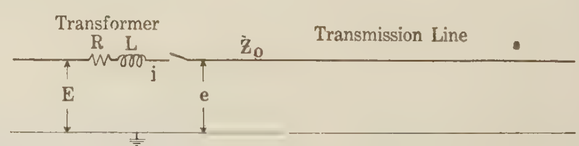


Fig. 4—Approximate Diagram of Transmission Line and Transformer

transformer referred to the high-tension, R and L are the equivalent resistance and leakage inductance of the transformer, and Z_0 is the surge impedance of the line with respect to ground. With E constant, the solution of (2) gives the equation of i:

$$i = \frac{E}{R + Z_0} \left[1 - \epsilon^{-\frac{R + Z_0}{L} t} \right] \tag{3}$$

From equation (1) it is evident that the voltage wave has the same shape as the current wave and its front extends over the same length of line. The current, from equation (3), will rise to almost its maximum value in a time equal to twice the time constant, $T = \frac{L}{R + Z_0}$. Thus, to accomplish a complete reflection, the line must have a minimum length of

TABLE I

LENGTHS OF OPEN-WIRE LINES NECESSARY FOR COMPLETE REFLECTION OF A SURGE GENERATED BY SWITCHING A LINE FROM A TRANSFORMER

Line kv.	Transf. capacity kv-a.	Amps.	Per cent R	Per cent X	R ohms	L henrys	Z_0 ohms	$T = \frac{L}{R + Z_0}$	$v\,T$ miles
220	60,000	157	0.7	9.0	5.7	0.194	500	0.000383	71.0
220	75,000	197	0.7	9.0	4.5	0.155	500	0.000307	57.0
220	100,000	262	0.7	9.0	3.4	0.116	500	0.000230	43.0
220	150,000	393	0.7	9.0	2.3	0.0777	500	0.000154	29.0
220	215,000	565	0.7	9.0	1.6	0.0540	500	0.000108	20.0
132	60,000	262	0.7	9.0	2.0	0.0692	525	0.000131	24.0
132	75,000	328	0.7	9.0	1.4	0.0480	525	0.0000912	17.0
132	100,000	437	0.7	9.0	1.2	0.0416	525	0.0000790	15.0
132	150,000	656	0.7	9.0	0.8	0.0276	525	0.0000525	10.0
110	45,000	236	0.7	9.0	1.8	0.0637	525	0.000121	21.0
110	60,000	315	0.7	9.0	1.4	0.0480	525	0.0000915	17.0
110	75,000	394	0.7	9.0	0.9	0.0308	525	0.0000585	11.0
110	100,000	525	0.7	9.0	0.8	0.0289	525	0.0000550	10.0
110	120,000	630	0.7	9.0	0.7	0.0241	525	0.0000458	8.5
66	30,000	262	0.9	8.0	1.0	0.0307	550	0.0000558	10.0
66	45,000	393	0.7	9.0	0.7	0.0230	550	0.0000418	7.8
66	60,000	525	0.7	9.0	0.5	0.0172	550	0.0000313	5.8
66	75,000	656	0.7	9.0	0.4	0.0138	550	0.0000251	4.7
66	100,000	875	0.7	9.0	0.3	0.0103	550	0.0000189	3.5
33	10,000	175	1.0	7.0	1.1	0.0201	575	0.0000349	6.5
33	20,000	350	1.0	7.0	0.5	0.0101	575	0.0000175	3.3
33	30,000	526	0.9	8.0	0.3	0.00769	575	0.0000133	2.5
33	45,000	790	0.7	9.0	0.2	0.00583	575	0.0000101	1.9
33	60,000	1050	0.7	9.0	0.1	0.00424	575	0.00000732	1.4
22	5,000	131	1.2	5.0	1.2	0.0127	575	0.0000221	4.1
22	10,000	262	1.0	5.0	0.5	0.00636	575	0.0000110	2.0
22	20,000	524	0.8	6.0	0.2	0.00397	575	0.00000690	1.3
22	30,000	787	0.7	7.0	0.1	0.00291	575	0.00000506	0.9
22	45,000	1180	0.7	7.0	0.08	0.00212	575	0.00000369	0.7

$v\,T$, where v is the rate of wave propagation, 186,000 miles (300,000 km.) per second. Table I shows the lengths of open-wire lines, of various voltages, necessary for complete reflections, when energized from transformers of capacities commensurate with the line voltages given. Since the surge impedance of a cable is approximately one-tenth, and the speed of propagation one-half of that of an open wire line, the lengths of cable required are approximately five times those given in the table. For a double reflection, giving nearly 4 E as discussed above, the cable must be connected to an open wire line twice as long. With the lengths of wave fronts generated on cables, it is evident that the lengths of cable and open-wire line necessary in a composite line for this double reflection are not common conditions. Further, with such lengths, the next factor discussed influences the situation.

Attenuation. The second factor tending to limit the surge potential is the attenuation of the wave. The attenuation factor of a line is:

$$\epsilon^{-\left(\frac{r}{2Z_0} + \frac{g\,Z_0}{2}\right)x}$$

where r is the series resistance and g the parallel conductance per unit length of line, Z_0 is the surge impedance, and x is the distance traveled in the same linear units used for r and g.

This reduces the wave as it travels down the line. In any case where there are abrupt wave fronts there are high-frequency components. The resistance of the conductor is higher to these high frequencies due to skin effect. Thus, the first term of the attenuation constant, $\frac{r\,x}{2\,Z_0}$ for the higher frequencies is many times its value using the d-c. resistance. This will tend to rapidly damp out the high-frequency components and slope the wave.

In the case of high voltages, corona enters and helps dissipate the energy of the surge[7]. This effect is higher for the more abrupt wave fronts. The effect of corona is to increase the second term of the attenuation constant $\frac{g\,Z_0\,x}{2}$. This term is negligible when only the leakage of the insulation is considered. For the higher voltages this second term is far greater than the first. Thus, when a surge above the corona voltage is generated, its energy is dissipated rapidly as the wave travels along the line. When the voltage has been reduced below the corona point, the wave proceeds, being governed by the first term of the attenuation constant, $\frac{r\,x}{2\,Z_0}$. This attenuates the wave more slowly.

It has been found in tests that extremely high voltage surges fall to a fraction of their original value in a distance of only a few miles. In several instances, a

7. For references see Bibliography.

surge was recorded at one station with a magnitude of 1000 kv. and at a station 35 miles away with a magnitude of 150 kv. It is believed that most of this attenuation took place in the first few miles. Lower valued surges which traveled 250 miles have been recorded.

Characteristics of an Arc. The considerations thus far discussed do not take into account any characteristic of the arc, which always takes place at the contacts of a switch. This may affect the results considerably.

Fig. 5a shows the static characteristic of an arc in air; that is, the variation between volts and amperes under slowly varying conditions. This gives the effect of a negative resistance and an approximate equation is $V = V_0 - I\, r_0$, where V is the voltage across the arc and r_0 is the value of negative resistance, or the slope of the straight line. This characteristic, however, is not maintained under rapidly varying conditions. Under such conditions there would have to be a rapid ionization and de-ionization of the air and the speed of these phenomena are limited. Fig. 5b shows the dynamic characteristic of the alternating current arc in air.

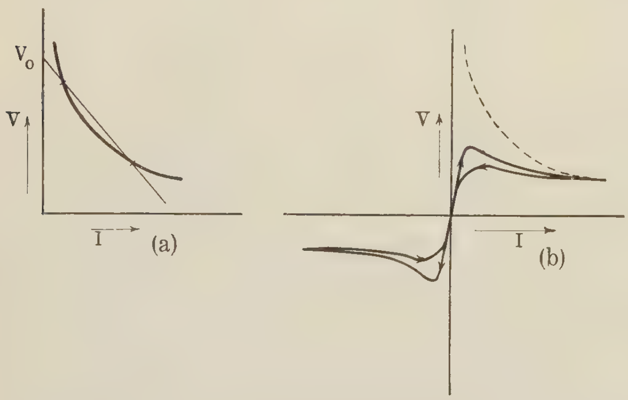


FIG. 5—CHARACTERISTICS OF AN ARC IN AIR
(a) Static (b) Dynamic

This characteristic is a function of both current and frequency. With small currents and low frequencies the characteristic approaches that of Fig. 5a. With heavy currents the intense ionization keeps the atmosphere of the arc conducting between alternations even at lower frequencies, while with light currents at higher frequencies there is not time for the de-ionization necessary to give the static characteristic. It is this characteristic, giving a low value of negative resistance at high frequencies, which minimizes the possibility of sustained high frequency oscillations on transmission lines. It is acknowledged that, if the negative resistance of the arc, in a sustained short circuit, were greater than the positive resistance of the connected circuit, oscillations with indefinitely increasing amplitude would be possible[2,8]. Tests have proved that these do not exist. Where the arc is in rapid air currents or a magnetic field the tendency is toward the static characteristic. An arc in oil also has a negative resistance characteristic, so the following discussion applies to oil-circuit-breaker, as well as air-break, switching.

Effect of the Arc in Switching. Where power currents are switched, the arc persists over any high-frequency oscillation and conditions are controlled by the 60-cycle wave. This is also true in the usual case of charging currents since appreciable currents usually are involved. In the case of closing either, the arc does not ordinarily extinguish after once striking. Where power current is interrupted the arc will extinguish at the zero

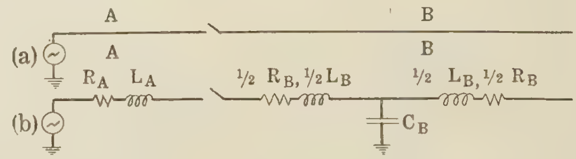


FIG. 6—TRANSMISSION LINE SUPPLIED FROM ALTERNATING CURRENT SOURCE

point of the current wave which is also at a low point of voltage. Also, when charging currents are interrupted, the arc will first extinguish at the zero point of the current wave, but this will be at the maximum of the voltage wave. In this case, surges three times normal are possible. For short lengths of line or station busses, where exceedingly small currents are involved, the arc maintains more of its static characteristic and higher potentials are possible.

Switching Charging Currents—Larger Values. The above considerations may be better explained in connection with the following diagrams; Fig. 6a represents one phase of an open end line. Fig. 6b represents the

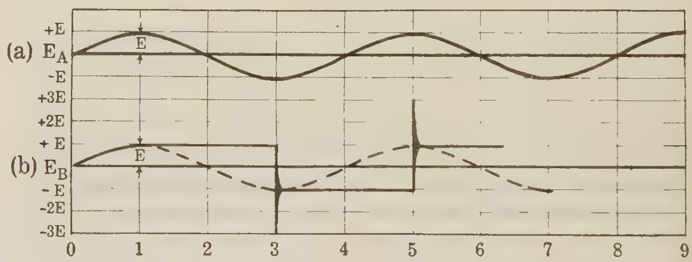


FIG. 7—SWITCHING CONTROLLED BY 60 CYCLE CONDITIONS
(a) Voltage on supply side of switch
(b) Voltage on line side of switch

approximate equivalent circuit. Fig. 7a shows the wave of voltage at the supply side of the switch. Fig. 7b shows the voltage on the line, or condenser. The arc between the switch contacts will first extinguish at 1, the zero point of the current wave and the crest of the voltage wave. This will leave the line charged to a maximum of E_m in one direction. The switch contacts are assumed to be separating continuously. From 1 to 3 the voltage across the switch contacts varies with the impressed voltage to a maximum of $2\,E_m$ at 3. There will be no restriking if at this time the contacts are too far apart to break down at $2\,E_m$. If not, reignition will occur, and there will be a resulting oscillation about the point of the applied

voltage E_A, or $-E_m$, and with an amplitude of $2E_m$, the amount of the transition to the new condition. It is obvious that the potential will thus reach a maximum of $-3E_m$ across the condenser. Since there is appreciable current the negative resistance of the arc is low and it will not extinguish during the high-frequency oscillation. This oscillation will then damp down to the applied voltage. Again, it will extinguish at that point, as shown between 3 and 5, leaving the condenser charged to a potential of $-E_m$. At 5 it may again re-ignite with a potential of $2E_m$ across the contacts. Here again the oscillation will have an amplitude of $2E_m$, giving a maximum of $3E_m$ across the condenser, and the oscillation will damp down to the applied voltage, where it will extinguish. It is evident that, no matter how often the arc reignites, the potential can never be higher than $3E_m$.

Switching Charging Currents—Small Values. When small currents are involved, it is possible under certain circumstances for the arc to extinguish at the zero point of the high-frequency current wave, and ignite at the

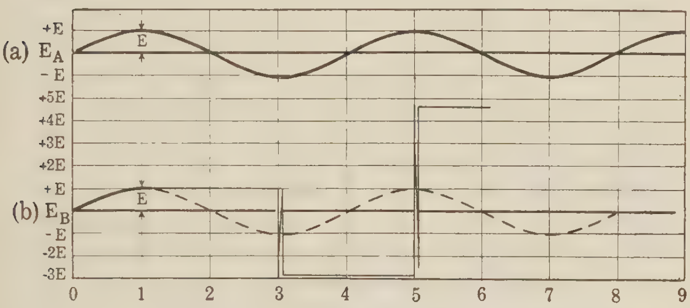


FIG. 8—SWITCHING CONTROLLED BY HIGH-FREQUENCY CONDITIONS

(a) Voltage on supply side of switch
(b) Voltage on line side of switch

crest of the 60-cycle wave. This situation is illustrated in Figs. 6 and 8 but in this case part *B* of the circuit is small and therefore takes small charging current. As in the previous case the arc between the contacts will extinguish at the crest of the 60-cycle wave at 1, Fig. 8B. The condenser will then be left charged to a potential of E_m. It is assumed that after one half-cycle, at 3, the switch separation is such that $2E_m$ will just reignite the arc. There will then be an oscillation with an amplitude of $2E_m$ about the applied voltage E_A, or $-E_m$. The potential across the condenser will thus reach a maximum of $-3E_m$. When this oscillation has damped to a value slightly less than $2E_m$ the arc may extinguish at the zero point of the high-frequency current wave and leave the condenser charged to slightly less than $-3E_m$. Again the voltage across the contacts will vary between points 3 and 5 to a maximum of $4E_n$ at 5 when it is assumed that the switch contacts have separated to a position where $4E_m$ will just reignite the arc. This time the oscillation will have a magnitude of something less than $4E_m$ about E_m which will bring the voltage across the condenser to a maximum of slightly less than $5E_m$. This process may be carried on with an increase of nearly $2E_m$ with each restriking of the arc.

While it is conceivable for the process discussed in the last paragraph to continue beyond two restrikings, it is extremely unlikely; and even two should be rare. There are many factors which tend to prevent the high frequency condition from controlling the situation. The theory assumes that the charging current to the section being disconnected is broken at the zero point of the high-frequency current wave after the first interruption. In the usual case of line switching the inductance and capacitance are both linear functions of the length of circuit. Thus, when the capacity is small, giving small currents, the inductance is also small and the frequencies are high. Usually these frequencies are high enough to maintain the arc over the high-frequency oscillation even though the currents are extremely small. The worst condition as discussed assumes that the rate of opening of the contacts is such that the breakdown is increased nearly $2E_m$ each half cycle of the applied voltage. Further, it is just as likely that in position 3 Fig. 8, the arc will extinguish leaving the bus charged $+E_m$ rather than $-3E_m$. In this case there would be no second restriking.

From the foregoing, it appears that high-speed switches would tend to prevent the higher voltage surges. If, after the first extinction, the separation of the contacts is so rapid that in one half-cycle its breakdown is more than $2E_m$, there can be no restriking. With the same speed of opening the breakdown between contacts in oil increases more rapidly than in air. Thus there should be greater freedom from surges from oil switch operations than air-break switch operations.

Closing operations should not cause potentials as high as opening operations. This is for the reason that the switch contacts are drawing continuously closer and therefore there should be at most only one restriking. This would limit the potentials obtainable to $2E_m$ on homogeneous lines. However, since switch contacts, especially disconnect switch contacts, are not perfect arcing contacts, it is possible for the second striking to be at a higher voltage than the first. This makes possible surges slightly higher than $2E_m$ from closing. It is fortunate that the higher surges come upon deenergizing since in this case the element of highest potential is being disconnected from the system and a flashover is not as serious. Further, there is usually the least apparatus connected to the part being disconnected.

In all the above it is assumed that the neutral of the system is held at ground potential. In the case of an isolated neutral system the potentials discussed above are aggravated by the amount of the shift of the neutral; that is by a maximum of 1.73.

Experimental Data. During the past three years, field tests using the klydonograph as a surge recorder

have been conducted on a large variety of open-wire and cable systems. These have given definite information as to the surges actually present on lines. The complete results of these tests are being given in a companion paper by Messrs. McAuley and Huggins and the writer. Certain of these data, however, will be discussed here in connection with the above theories.

Switching in general caused no serious surges. The majority of switch operations produced no overpotentials and the majority of the surges which were produced were less than two times normal. Occasionally higher voltage surges occurred, but these were rare. This would be expected due to the small chance of the simultaneous presence, during a switching operation, of all the conditions and events necessary for their production as discussed above. Surges due to switching load currents or energizing lines were of the lower values. The higher surges always resulted from low energy operations, such as switching short lengths of line or busses. Many of these higher ones were caused by de-energizing busses or open oil switches with disconnect switches. As examples: In a test on a 220-kv. grounded-neutral system, with instruments at four points, about 3600 high-tension, oil-switch operations were performed. Approximately one-fourth of these caused surges. The largest surge recorded was 3.2 times normal due to de-energizing a 40-mi. section of the line. The next highest were two 2.7 times normal due to opening a bus. On a 140-kv. isolated-neutral system in ten months tests at four points there were five surges between 3.0 and 4.6 times normal. On a 120-kv. grounded-neutral system during ten months normal operation with recorders at four points there was one surge six times normal, one 4.0, one 3.7, and five between 3.7 and 3.0 times normal. All of the above were caused by idle-line switching, and the higher ones by de-energizing operations.

On cable systems, due to the higher charging currents per unit length, the higher attenuation constant, the longer initial wave fronts, and the denser networks usually encountered, milder surge conditions would be expected. This is what was actually found: The maximum surges recorded due to cable switching were of the order of 2.5 times normal. In one test, after a year's operation, a surge 4.5 times normal was recorded. However, this was due to energizing a switch group and not strictly a cable operation. On another test, high surges resulting from opening a bus section prompted a series of tests. The highest values were as follows:

Opening bus with disconnect switches—4.5 times normal.

Closing bus with disconnect switches—2.9 times normal.

Opening bus and transformer with oil switches—4.3 times normal.

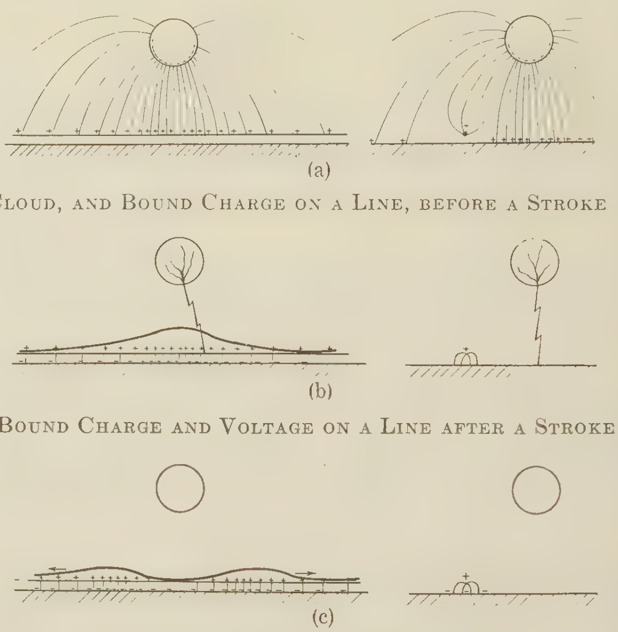
Closing bus and transformer with oil switches—2.9 times normal.

Both of these conditions are low-current operations. Although the current would be larger with the transformer connected, the natural period of the circuit would also be longer, thus permitting the action discussed under "Charging Currents—Small Values."

II. Lightning

The principal characteristics of lightning of interest in connection with its effect on transmission lines are; the gradient of the field produced by the cloud charge; the nature of the discharge, that is, its rate, and whether it is unidirectional or oscillatory; and the polarity of the cloud. Ryan, De Blois, Norinder, Creighton, Peek, Simpson and others have all contributed towards our present knowledge.

From any isolated charged body in the atmosphere there is an electrostatic field ending in an equal charge of opposite polarity gathered on the earth. As a charged cloud approaches a transmission line, a charge, opposite in sign to that on the cloud, gathers on the line. Since the cloud approaches slowly, the charge passes up from the ground through the neutral or leaks over the insulators. This charge in the presence of the field keeps the line at zero potential with respect to the earth. Fig. 9a illustrates this condition. Upon the stroke of lightning the field disappears and, if the collapse be rapid, leaves the charge bound on the line. If the collapse is instantaneous this raises the line potential to a voltage corresponding to the field before the stroke, but opposite in sign. The magnitude of this voltage is the product of the change in field gradient and the height of the line. Upon the disappearance of the field, the charge divides in the center and propagates a traveling wave in each direction as shown in Fig. 9c. Each of these waves has a magnitude equal to one half of that of the initial voltage directly under the cloud. It is readily seen that the rate of rise of voltage, and the maximum magnitude, on that part of the line occupied by the charge before the stroke, is



(a) Cloud, and Bound Charge on a Line, before a Stroke

(b) Bound Charge and Voltage on a Line after a Stroke

(c) Traveling Waves after a Stroke

Fig. 9

determined by the rate of discharge of the cloud, as well as the value of the field destroyed. The reason for this is, that while the cloud is discharging part of the charge is traveling out and increases the length of the surge, but reduces its magnitude. On the remainder of the line to which the traveling wave goes, the rate of rise of voltage is determined by the wave front, that is, the space configuration of the charge liberated, as well as, by the rate of discharge of the cloud. It is obvious that for this phenomena to take place the cloud must discharge rapidly, that is, in a few microseconds. Otherwise the charge will have time to spread out over the line gradually, without causing an appreciable rise in voltage. The amount of this rise is determined by the ratio of the length of the line occupied by the bound charge to the total length of the line, and the change of field gradient caused by the stroke. Also, if the neutral of the transformers is grounded and the discharge is slow, the charge may pass to earth through the short-circuit impedance of the transformers.

Norinder. In 1924, Dr. H. Norinder published the results of his tests in Sweden.[11] These tests, which contributed a valuable addition to our knowledge of lightning, consisted of extensive measurements of the actual intensities, and variations of the cloud field. Most of the data were measurements with a static voltmeter of the potential induced on highly insulated wires by the cloud field. Other measurements were made with a cathode-ray oscillograph of the potential induced on an antenna, grounded through a high damping resistance, by the lightning discharge. Still others were made with the ordinary oscillograph of the discharge-induced potential.

Although the inherent variation of the physical conditions under which lightning occurs is reflected in the data, the salient points in Norinder's results were as follows: The gradient of the cloud field at the height of the average transmission line was often of the order of 30 to 45 kv. per ft. (100 to 150 kv. per m.) and occasionally 60 kv. per ft. (200 kv. per m.). Dr. Norinder estimated the gradient near the lightning path to have been 90 to 120 kv. per ft. (300 to 400 kv. per m.); the cloud was just as often positive as negative. One of his charts showed the potential reversing during the passage of the cloud. The range of influence of the usual stroke was over 1.3 mi. (2.3 km.) and under 6.2 mi. (10 km.); the discharge was non-oscillatory; and the discharge was relatively slow, the induced potential on the antenna rising to a maximum in the order of 0.01 to 0.02 sec. From the results Dr. Norinder drew various conclusions some of which pertained to the operation of transmission lines.

Since both the data and the conclusions were somewhat at variance with current opinion on the matter, both were criticized rather severely.[12] The most disturbing feature of these data was the long wave fronts indicated. If lightning strokes were as slow as 0.01 sec., it would be impossible for surges as actually experienced to be induced on transmission lines. In a time of this order the bound charge could travel the length of the line many times and distribute itself over the line or leak off through the terminal apparatus. It is evident that the strokes which produce the surges experienced must take only a few microseconds to discharge the cloud. While some of the conclusions seem rather loosely drawn, there does not seem to be anything wrong with the methods used in obtaining the data. The ordinary oscillograph is not fast enough to record wave fronts of only a few microseconds. However, the fact that some of the oscillograms showed a wave front considerably longer than the minimum which the ordinary oscillograph would have recorded satisfactorily, indicated that these long wave fronts actually occurred. While the above facts seem to be inconsistent, recent information shows that they are not. This will be discussed later.

Simpson. In March, 1926, Dr. G. C. Simpson presented to the Royal Society an excellent paper on lightning. It is not feasible to repeat the complete theory here and the reader is referred to the original paper.[13] Briefly, the author stated that when a point on a positive cloud reaches a state of electrical intensity at which ionization begins, the point proceeds towards earth, forming a conducting channel of ionized air. The point of this channel attracts negative electrons from the surrounding atmosphere. These electrons being very mobile pass up the channel and spread out into the cloud. This leaves the channel positive and it thus burrows its way to the earth. The channel may branch but each fork remains pointed and the stress high. The rate at which the channel can grow is determined by the rate at which the cloud can absorb the negative electrons. As the electrons pass into the cloud they soon become negative ions, after which their speed is reduced; thus they tend to block up the mouth of the channel and prevent further flow. This accumulation of ions disperses in the cloud, the field is again established and the flow continues if the ions in the channel have not had time to recombine entirely. Thus the flow will be slow or even intermittent. The intermittent flow is most marked in a discharge from one cloud to another.

With a negative cloud the process is different. If the formation of a channel toward earth at the point of highest stress is assumed, the point of the channel attracts positive ions from the surrounding atmosphere. These ions, being relatively immobile, are unable to pass up the channel rapidly. They thus neutralize the point which reduces the stress and the point spreads out. In this way the charge in the cloud is held until the stress at the earth's surface is high enough to start a channel. This channel operates as discussed above, for the positive cloud, with the following exceptions: The negative electrons are able to spread out readily in the ground, and the channel instead of passing into a region of lower stress continues always into a region of greater stress. The average stress is much higher. There is not the tendency to branch, as the field concentrates towards a smaller area, until the cloud is

reached where it branches out and discharges a large volume of the cloud in a single flash. Thus the negative cloud discharges rapidly and violently.

Dr. Simpson substantiated the above theory with laboratory studies of discharges in conjunction with a large number of photographs of actual lightning strokes. Out of 442 photographs studied, 242 showed branches downward indicating positive cloud discharges, three were negative strokes with branches upward, and 173 were unbranched. Since the negative branches are within the cloud, in general they would be obscured. It was further pointed out that in all cases branches were less intense than trunks and that many of the 173 apparently unbranched strokes likely had branches downward which were obscured by the rain. Dr. Simpson divided the unbranched discharges into equal parts which made in all 328 positive strokes and 89 negative strokes, or nearly 4 to 1. He expressed the opinion that even this is too small a ratio.

Quoting Dr. Simpson, "If this reasoning is correct lightning flashes between earth and a negatively charged cloud will be much more intense than flashes to a positively charged cloud, although the two clouds may be charged to the same intensity. In fact one would expect on this reasoning that discharges from positively charged clouds would be frequent but weak, while discharges from negatively charged clouds would be infrequent but very strong."

Experimental Data. In transmission line surge investigations with the klydonograph it has been found that there are surprisingly few surges induced in a given locality during a thunder storm. Instead of surges of varying magnitude to correspond to the numerous lightning flashes usually observed during a storm, there result only from one to perhaps 10 surges; usually not more than two. Further, it has been found that practically all of these lightning surges are positive. The few negative surges recorded are always high and abrupt. Of these negative surges some are definitely known to have been caused by direct strokes. Bearing in mind that an induced surge is of opposite polarity to the cloud and that a direct stroke is of the same polarity, the above results indicate, at first sight, that all clouds are negative. The number of surges recorded, however, is not consistent with the numerous flashes visible during a storm.

These data, when analyzed in the light of Dr. Simpson's theories and Dr. Norinder's results, seem to substantiate both. Most of the lightning strokes are from a positive cloud. Perhaps as many clouds are negative, but the positive clouds discharge more frequently. These positive strokes are relatively slow, having a wave front of the order of 0.01 seconds, as shown by Norinder. They are slow enough to permit the bound charge to distribute itself over the line or to escape through the transformer neutral, as discussed above. Even on an isolated neutral line, where the charge does not escape, its distribution over the usual power line prevents a greater rise than a few thousand volts, which is negligible. It may be serious on communication lines, which are isolated from ground and insulated for low voltages. Tests on communication lines have shown more negative surges than tests on power lines. The effect of positive strokes may also be important on isolated neutral lines which are so short that the entire line is in the field destroyed by a single stroke. According to Norinder, this length would be of the order of two miles. Further, the effect of a positive stroke is less severe, due to the fact that less of the cloud is discharged and therefore less of the field is destroyed by a positive stroke. The negative clouds discharge violently but less frequently. They discharge a greater volume of cloud and hence destroy a larger field. The time of discharge is of the order of three microseconds, which is too brief to permit a bound charge on the line to dissipate, and hence high voltages are induced. Likely, Dr. Norinder's apparatus was not sufficiently rapid to detect these negative strokes in their true shape. Klydonograph records also indicate that direct strokes have abrupt wave fronts. These records show that induced strokes have wave fronts from a few microseconds to over 100 microseconds. As mentioned above, the measured rate of rise of voltage due to induced strokes depends upon whether the measurement is made at the position of the initial bound charge or at some other point of the line. The records agree with both Simpson and Norinder in that they indicate that the stroke is unidirectional. An oscillatory surge on the line may result, however, if the stroke causes a flashover.

It was found that the maximum surge potentials appearing on lines of various operating voltages are approximately a constant times the normal voltage. That is, the maximum surges are from 10 to 15 times the normal crest voltage above ground. This indicates that the lightning stroke is not faster than the insulator flashover at these high over-voltages. When the insulator flashes over the charge is released and the voltage can go no higher. It should be remembered that the higher the over-voltage, the less the time lag of breakdown of any dielectric.

III. Conclusions

The following conclusions may be stated:

Switching. 1. If there were no attenuation, a switch closure on a cable connected to an open-ended, open-wire line would reflect with nearly four times the applied voltage.

2. In practise, increase in the attenuation constant, due to steep wave fronts and to corona at high voltages, prevents high-potential steep-front waves from traveling long distances.

3. The limitations of the source from which a line is switched limit the steepness of wave front possible.

4. The characteristics of the arc at the switch contacts influence the surges caused by switch operations. It has been shown that over-potentials caused by low-

energy charging current operations are more severe than those caused by power or heavy charging current operations. Thus de-energizing short lines or busses causes the highest surges.

5. No switching operations cause surges high enough, or with a duration long enough, to affect the operation of properly insulated lines. Only rarely is a surge above 2.0 times normal produced.

Lightning. 1. Positive lightning strokes are frequent but weak. They are slow, of the order of 0.01 seconds, and hence do not induce surges on transmission lines.

2. Positive strokes, even though slow, may produce surges of importance on isolated low-voltage lines, such as communication lines.

3. Negative lightning strokes are less frequent but more violent. They discharge in about three microseconds and hence produce high voltage surges on transmission lines.

4. The field gradient is often as high as 60 kv. per ft. and may reach 100 kv. per ft. Thus a surge of over 2000 kv. might be induced upon a line of ordinary height with sufficiently high insulation. Eighteen hundred kv. has been recorded by the klydonograph.

5. The time lag of an insulator flashover is less than the time of discharge of a negative stroke and thus the impulse flashover voltage of the insulators limits the possible potential.

6. The stroke of lightning itself is unidirectional. If an oscillatory surge due to lightning is recorded, it is a line oscillation resulting from a flashover.

ACKNOWLEDGMENTS

The author is pleased to acknowledge his indebtedness to Mr. J. F. Peters and Dr. J. Slepian for their numerous suggestions and to Mr. P. H. McAuley for his suggestions and help in the preparation of this paper.

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ISOLATION FOR FIRE FIGHTING

Fires are expensive and seriously affect electric service. Unfortunately, so long as oil and combustibles are used for insulation and so long as electrical energy behaves as it does there will always be fire hazards to trouble the industry. Progress in eliminating these hazards has, however, been made in the last few years. The principle of isolation has been used to good advantage in many parts of typical systems. In recent hydroelectric stations, all apparatus containing oil has been placed outside the station structure. In metropolitan substations oil-filled equipment has been placed in fireproof compartments. Care in installation, precaution in handling oil and better inspection and maintenance of the oil have reduced the danger.

More recently the principle of isolation has been combined with methods of fighting fire. Placing any piece of equipment in a fireproof compartment reduces the fire hazard to the minimum, and fires originating in these isolated equipments can be extinguished by any one of several means. In some metropolitan substations all transformers and regulators are placed in separate compartments as well as in one fireproof room. Permanently located fire-fighting equipment which can be used in any compartment or in the room itself without risk to those who operate the extinguishing chemicals is then installed. Generators have been totally inclosed and extinguishing chemicals installed for flooding the machine in the event of a fire.

None of these more elaborate fire-prevention installations has been called upon to operate under service fire conditions, but the money spent and the precautions taken indicate the progress the industry is making and show that it is alert to every reasonable opportunity for reducing damage by fire.—*Electrical World.*

Abridgment of

Space Charge and Current in Alternating Corona

BY C. H. WILLIS*

Associate, A. I. E. E.

***Synopsis.**—1. The physical nature of ionization in a corona discharge in air is studied; by means of the corona spectrum, the saturation current in air around the corona voltage, and the influence of the material of the wire on the saturation current. The results indicate that nitrogen only is ionized in a corona discharge in air; that the ionization of the nitrogen results in the separation of an electron from the nitrogen molecule; and that the electron quickly attaches to a molecule or group of molecules, probably water or oxygen, to form an ion.*

2. The free charge in the neighborhood of the wire called the space charge, is found to be alternating in character and to have a definite boundary. The space charge formed on any half-wave returns to the wire on the next succeeding half-wave.

3. The mobility of the ions is calculated from the boundary of the space charge. A limiting value of about 10 cm./sec. per volt/cm. is indicated for the positive ions. The negative ions show no sign of a limiting value and the mobility varies from about 1.6 to 10 cm./sec. per volt/cm. as the maximum impressed voltage rises from the corona voltage to twice the corona voltage.

4. Ionization is found to occur at lower voltages on the positive half-waves than on the negative half-waves and the ionization on the positive half-waves becomes much more copious with the beginning of ionization on the negative half-waves.

5. A formula for the corona current based on theoretical considerations is developed by the aid of certain empirical assumptions. This formula gives excellent agreement with the observed currents measured in large cylinders. A calculation of the corona current for a 100-mile three-phase transmission line gives a satisfactory agreement with the values of current as measured by W. W. Lewis.

* * * * *

Introduction

RECENT studies of corona in various gases have revealed a number of anomalies from the standpoint of Towsend's theory of ionization by collision.[20] I twas the purpose of this investigation to obtain further evidence of the physical nature of the ionization in the case of corona, and to study the space charge surrounding the corona wire in the hope that information leading to an analytical expression for the corona current, corona loss, and extra capacity due to corona, might be obtained.

The electrode arrangement chosen for the study of

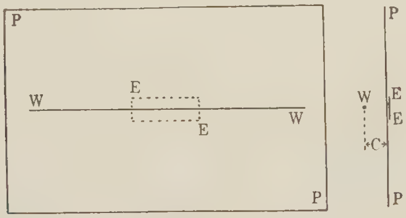

Fig. 1

the ionization and space charge was a wire and large plane, as this gives a representation of half of a two wire transmission line, and permits an easy adjustment of the distance between electrodes. See Figs. 1 and 2; *P P* represents a plane, 270 cm. by 420. cm., made of copper screen wire, No. 16 mesh, *E E* represents a copper electrode, 30 cm. by 91.5 cm. and about 0.2 cm. back of the plane; *W W* represents the corona wire 355 cm. long. The sizes of wire used and the distances used between the wire and the plane are given in the corresponding data.

Electrode *E E* is connected to a battery through a galvanometer *G* and a protective resistance *R*. By making *E E* positive with respect to the grounded plane *P P*, a portion of any negative ionic charge arriving at the plane will be drawn through the meshes of the wire to the electrode and cause a deflection of the galvanometer *G*. By reversing the potential of the electrode *E E* a portion of the positive ions arriving at the plane will be drawn to the electrode and cause a deflection of the galvanometer in the opposite direction. This is essentially the same method described by Whitehead in 1912.[13]

Spectrum of Corona

The spectrum of the corona light was photographed by means of a sensitive spectroscope, through the courtesy of Dr. R. W. Wood. The spectrum showed

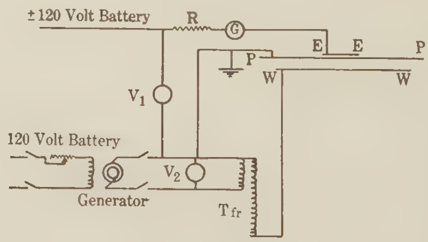

Fig. 2

the band spectrum of nitrogen but no trace of the oxygen spectrum even at a voltage twice the corona voltage. These results are in accord with the spectrum of the arc in nitrogen, as studied by K. T. Compton[39] and the point discharge in air as studied by U. Yoshida and H. Hirata.[42]

The corona spectrum, a band spectrum, indicates that the ionization in corona is the breaking off of electrons from a neutral molecule and not the dissociation of nitrogen molecules into atoms. The

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20. For references see Bibliography published with complete paper.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 7-11, 1927.

absence of the oxygen spectrum indicates that the oxygen does not play any appreciable part in the corona ionization. This is surprising in view of the fact that the gradient for corona in pure oxygen is below that for corona in air or pure nitrogen.[46]

Conduction Current in Air Near the Corona Voltage

In order to obtain further information on the physical nature of the ionization in corona, the conduction current of the air was measured as the voltage approaches the corona value. Whitehead,[11] and Lee and Kurrelmeyer[46] found no effect on the corona voltage due to ionization of the air by external means. A quartz mercury arc was therefore used to increase the conductivity of the air to give an appreciable saturation current.

The corona voltage was found to lie above the point at which ionization by collision can first be detected by the rise in the saturation current. The corona voltage, therefore, represents a condition of unstable equilibrium in the process of ionization by collision. This will be discussed later.

Measurement of the conduction current from copper and magnesium wires shows no influence due to the material of the wire. This strongly indicates that Towsend's assumption[20] that the positive ions were ionizing agents is correct altho direct measurement of the ionization by positive ions has given negative results.[31,32,49]

Theory of Space Charge (Wire and Concentric Cylinder)

It is generally accepted that the region of ionization in corona is a thin layer of the gas around the wire. Under this condition the ions formed of the same sign as the potential of the wire are driven out while the ions formed of the sign opposite to the potential of the wire will be drawn into the wire at once. On reaching the wire the charge of these ions flows immediately through the conductor of the potential source to the opposite electrode. It is the flow of this charge that constitutes the corona current.

During the time that the charge of sign opposite to the potential of the wire is passing from the region of ionization to the wire and then to the opposite electrode, the charge of the same sign as the potential of the wire moves very little because the charges move much more slowly through air than through a conductor. The charge of the same sign as the potential of the wire is then left as a space charge immediately surrounding the wire when the charge of the opposite sign reaches the opposite electrode. The energy represented by the corona current flowing through the high-tension circuit is now stored as an electric displacement between the space charge and the charge on the opposite electrode. See Fig. 3A.

So far, the corona wire and the opposite electrode have behaved just as a condenser, but there is this important difference; the space charge is free to move under the action of the electric field, and as the space charge does move out, the energy stored in it is dissipated, reappearing in other forms.

If the source of potential is continuous, this space charge will reach the opposite electrode and all of the energy will be dissipated. If the source of potential is alternating, however, the space charge may or may not have time to reach the opposite electrode before the potential reverses, depending on the frequency and the distance between the electrodes.

Under these conditions the behavior of the space charge may be accurately represented by a circuit composed of a resistance in series with a capacity. Fig. 3A represents the condition just after a layer of space charge has been formed, and Fig. 3B represents

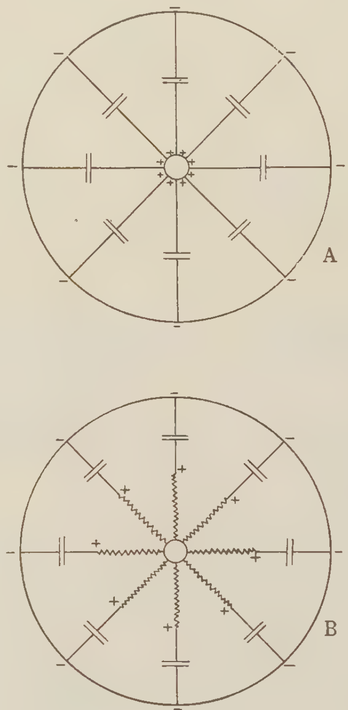

Fig. 3

the condition after this layer has moved out a distance from the wire. It must not be assumed that the entire space charge is formed instantly and in one layer, for its formation starts when the voltage passes the corona voltage and continues certainly past the crest of the voltage wave. Figs. 3A and 3B refer to any particular layer of the space charge.

An ion formed at any point on a voltage wave will have the time of the remainder of that wave for its outward journey and the entire succeeding wave in which to return. All ions will therefore have more time in which to return to the wire than they have for their outward path, since ionization does not begin until the instantaneous voltage has risen to the corona voltage. If, then, we neglect diffusion and the slowing down of ions, due to the formation of molecular aggregates, all

of the space charge which does not reach the opposite electrode before the voltage reverses should return to the wire at which it was formed during the voltage half-wave succeeding that on which it was formed.

The returning space charge, of course, meets the outgoing space charge and any recombination between these two is equivalent to a return of the space charge to the wire. Recombination therefore increases the probability of the return of all of the space charge to the wire.

The corona loss is due to the movement of the space

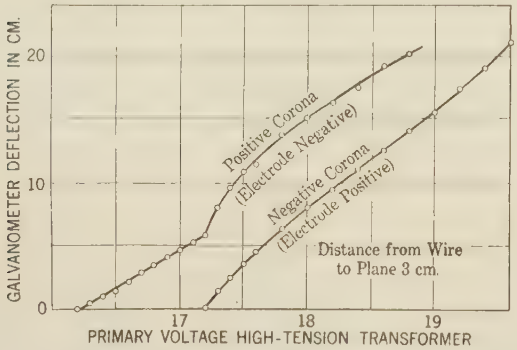

Fig. 8—Corona Discharge Curves. Temperature 21.6 Deg. Cent., Barometer 75.4 Cm., Frequency 59.5 Cycles. Wire Diameter 0.440 Mm. Transformer Ratio 401

charge through the electric field surrounding the wire. We may concentrate our attention on any average ion of the space charge. Beginning just after its formation at the surface of the wire, and assuming that the ion has the average velocity of thermal agitation, this ion will be accelerated by a force due to the electric field.

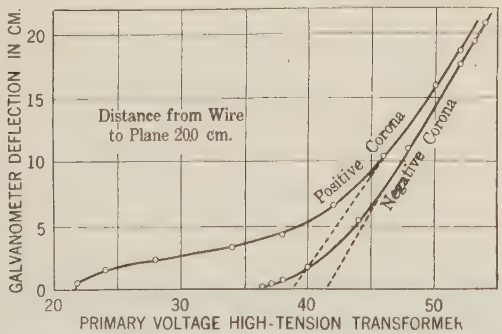

Fig. 9—Corona Discharge Curves. Temperature 24.4 Deg. Cent., Barometer 75.4 Cm., Frequency 59.5 Cycles, Wire Diameter 0.440 Mm. Transformer Ratio 401

As the ion moves through a free path, its velocity increases due to the acceleration. At the first collision between the ions under consideration and a neutral molecule the ion loses a part of the energy gained from the electric field, to the neutral molecule, even though the collision be perfectly elastic. The ion will start its second free path, however, with a velocity greater than the average velocity of thermal agitation and therefore will have a higher velocity at the end of its second free path than at the end of its first free path. It will therefore lose more energy in the second collision. In this manner the velocity of the ion rises above the mean velocity of thermal agitation, to a value called the terminal velocity,[40] which is such that the ion loses as much energy at a collision as it gains during a free path. (The ion requires a number of collisions to reach this terminal velocity, and the terminal velocity, of course, varies with the field in which the ion travels.)

If the terminal velocity of the ion attains a value sufficient to ionize a neutral molecule, ionization occurs and the ion loses practically all of its energy and must then start the process of building up its terminal velocity again. From this it is evident that as the space charge moves through the electric field the energy stored in the space charge is converted into heat in the elastic collisions between ions and molecules or in case of an inelastic collision may produce a disturbance of the atomic structure resulting in ionization or sometimes only the radiation of light. This conversion of electric energy into heat, light, and free charge, constitutes the corona loss.

In the case of the space charge not reaching the op-

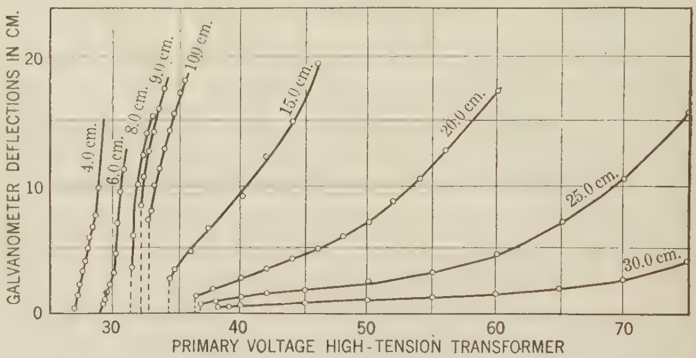

Fig. 10—Galvanometer Deflections vs. Primary Voltage for Corona on Positive Half-Waves. Temperature 18.9 Deg. Cent., Barometer 76.9., Diameter Wire 1.00 Mm. Ratio of Transformer 401

posite electrode, some of the energy stored in the space charge is not dissipated because the ions do not travel through the entire potential difference. The energy stored in the space charge and not dissipated by the ions as they travel out is returned to the system and results in the extra capacity effect observed in corona.

Break in the Discharge Curve for Positive Corona

As shown above, when corona forms at the crest of the voltage wave, the ions produced have a quarter period for their outward journey and the next succeeding half period in which to return. Under these conditions, all of the space charge produced in any half wave returns during the next half wave and there is a definite boundary beyond which none of the space charge is found. (See Figs. 14 and 15). Typical curves of the galvanometer deflections (proportional to the charge reaching the plane) against voltage are shown in Figs. 8 and 9. Fig. 8 gives the type of curves found

when the wire is close to the plane. Fig. 9 shows the curves found when the air is distant from the plane.

The break in the curves for the positive corona shown in Fig. 8 is due to the start of negative corona on the opposite half waves. In order to establish this point definitely, a battery was connected in series with the high-voltage winding of the transformer. In this way the a-c. voltage may be given either a positive or a negative bias. Under these conditions the start of positive corona appears at a constant value of the maximum positive voltage, while the break of the positive corona appears at an approximately constant value of the maximum negative voltage.

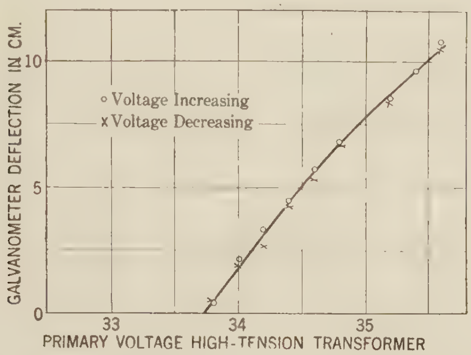

Fig. 11—Positive Corona. Distance from Wire to Plane 4.0 Cm.

This break in the discharge curve for positive corona is of considerable interest in view of the fact that previous observers have found only one voltage for alternating corona, but different voltages for positive and negative continuous corona. An inspection of the curves shown in Fig. 10 illustrates that the portion of the positive discharge curve previous to the break is found only at distances from the wire to plane less than 8.0 cm. for a 1.0-mm. wire. With greater distances than this, the first appearance of the positive corona is not detected by the test electrode. In no case was it possible to detect the first appearance of the positive corona by visual or aural means.

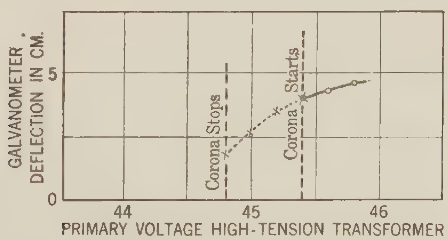

Fig. 12—Negative Corona. Distance from Wire to Plane 16.0 Cm.

Distortion of Electrostatic Field Due to Returning Space Charge

It is to be expected that the space charge of a previous half wave will distort the electrostatic field as it returns to the wire. Evidence of this is found in the fact that the negative corona ceases at a lower value of the effective voltage than that at which it starts, when the wire is far enough from the plane to permit the return of the positive space charge. When, however, the wire is so close that the positive space charge reaches the plane and does not return, the values of the voltage for the start and stop of corona coincide.

This effect is shown in Figs. 11 and 12. Fig. 11 with the wire 4 cm. from the plane, shows that the curve of positive discharge for increasing voltage coincides with the curve for decreasing voltage. The same was found true for the negative corona at this distance. Fig. 12, with the wire 16 cm. from the plane, shows that the curve for negative corona with decreasing voltages extends below the start of the curve for increasing voltages.

Boundary of the Space Charge

The curves shown in Figs. 10 and 13 give galvanometer deflections against voltage for a number of distances between the wire and plane. The start of

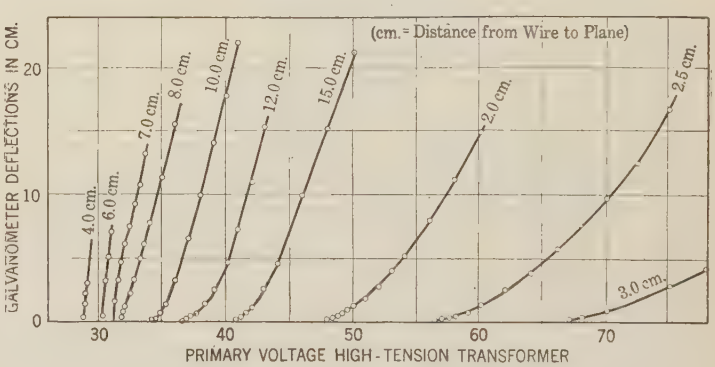

Fig. 13—Galvanometer Deflection vs. Primary Voltage for Corona on Negative Half-Waves. Temperature 18.9 Deg. Cent., Barometer 76.9 Cm., Diameter Wire 1.00 Mm. Ratio of Transformer 401

positive corona for distances below 7 cm. is given by the intersection of the discharge curve with the axis. Calculating the gradient for the start of positive corona, we find this constant, and using this value of the gradient, we can calculate the voltage for the start of positive corona for greater distances between the wire and plane. In this manner, the primary voltage for the start of positive corona with 15 cm. between the wire and plane was calculated to be 33.6 primary volts. At a high-tension voltage, 400 effective volts above the corona voltage the primary voltage would be 34.6 volts. At this voltage, the galvanometer deflection was 3 cm. In a similar manner we can find the galvanometer deflection at 400 effective volts above the corona voltage for all distances between the wire and plane. We thus obtain the relation between galvanometer deflections (or space charge reaching the plane) and the distance between wire and plane for a given rise in voltage above the corona voltage. Curves of this type for positive corona are shown in Fig. 14. They refer,

however, to a different size of wire from that used for the curves in Fig. 10.

The three small curves shown in the lower left hand corner of Fig. 14 give the charge reaching the plane for voltage increments insufficient to cause negative corona. These curves intersect sharply with the axis and this intersection is the boundary of the space charge at that voltage. Thus, with 100 volts above the positive corona voltage, no ions can be detected at a distance greater than 5.2 cm. from a 0.1-cm. wire. If the voltage rises 200 effective volts above the positive corona voltage, the boundary of the positive space charge is 5.6 cm. from the wire. A few readings were taken at 40 and 80 cycles, showing that the boundary of the space charge depends on the frequency. The machine used, however, was not suited to these speeds. The results shown all refer to 60 cycles.

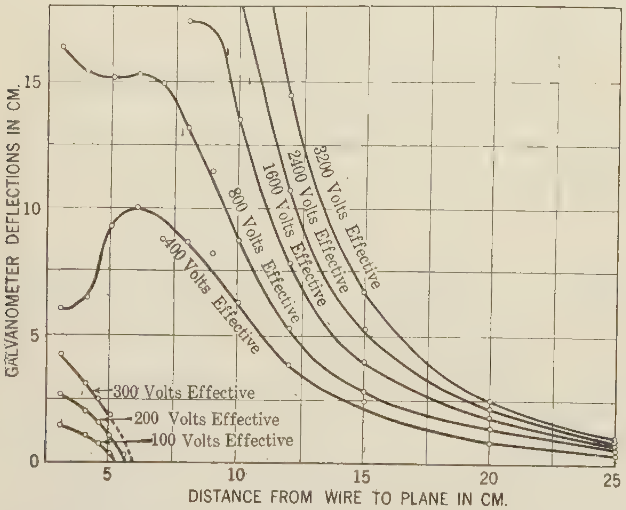

Fig. 14—Curves Showing Boundary of Positive Space Charge as Voltage Increases above Corona. Temperature 24 Deg. Cent., Barometer 75.5 Cm., Diameter Wire 0.440 Mm.

If the voltage rises 400 volts above the positive corona voltage, negative corona also forms. The start of negative corona influences the quantity of the positive discharge greatly and it also greatly increases the mobility of the charge as shown by the fact that the sharp drop in the curve comes at a much greater distance from the wire. Above the negative corona voltage the discharge curves for positive charge do not cut the axis sharply, but approach asymtotically. This is believed to be due to diffusion. With the great increase in the density of the charge, the effect of diffusion would be more important; also, as the voltage is carried higher and higher above the corona value, the time during which the first charges can travel out approaches nearer and nearer to the time they have to return; that is, a half wave. We would expect, therefore, more and more charge to be carried out by diffusion as the voltage rises above the corona value. The discharge curves, however, descend quite rapidly in every case and this marks the practical boundary of the space charge.

The maximum shown in the curves for 400 and 800 volts above the corona value is probably due to the fact that, with a very small distance between the wire and plane, most of the negative charge reaches the plane and therefore the effect on the positive charge is less important with small distances. This maximum should become less prominent as the voltage is raised because in that case the last charges formed will have a shorter time to travel out and therefore the amount of charge returning to the wire will be greater as the voltage is raised.

The curves shown in Fig. 15 are constructed in a similar manner for the negative charge, except that in the case of the negative charge, the start of negative corona can be detected at any distance from the wire to plane as the first appearance of positive charge. These curves for negative charge all show a sharp intersection with the axis and a definite boundary of the negative space charge. Since the positive charge is more mobile than the negative charge, (except for very high increments of voltage above the corona voltage), and since the positive corona starts at lower voltages for the wires used, the negative ions which fail to return

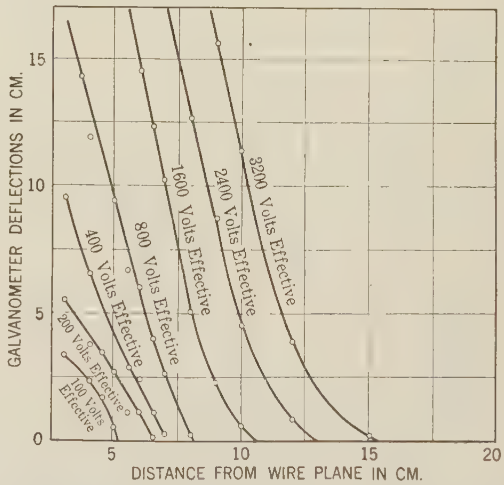

Fig. 15—Curves Showing Boundary of Negative Space Charge as Voltage Increases above Corona. Temperature 24 Deg. Cent., Barometer 75.5 Cm., Wire Diameter 0.440 Mm.

to the wire are probably destroyed by recombination. This prevents the curves for negative corona from becoming asymtotic to the axis.

Mobility of Ions in Corona Discharge

Ions moving through a gas under the action of an electric field approximately obey the laws for bodies moving in a viscous medium; that is, the velocity is approximately proportional to the field strength. The mobility K is defined as the velocity of an ion in a unit field. K is usually given in cm./sec. per volt/cm. By determining the boundary of the space charge and assuming that the ions travel along the shortest path

from the wire to the plane, we can calculate the mobility of the ions in the corona discharge. Some of the mobilities calculated in this manner are shown in the curves of Figs. 16 and 17.

The initial values of the mobility check very well with the values given by the physicists, varying from 1.3 to 1.8 cm./sec. per volt/cm. for the positive ions and from 1.6 to 2.2 cm./sec. per volt/cm. for the negative ions. The mobility of the positive ions rises quite rapidly with the appearance of negative corona and

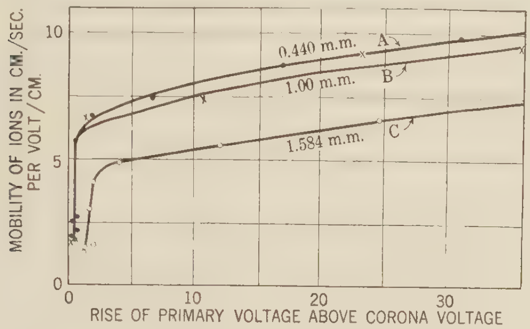

Fig. 16—Mobility of Positive Ions

A—Barometer 75.5 cm., Temperature 23,3-24.5 deg. cent., Humidity 8.6 mm. Hg.
B—Barometer 76.9 cm., Temperature 17.8-20 deg. cent.
C—Barometer 76.2 cm., Temperature 17.6-23 deg. cent., Hunidity 7.4 mm. Hg.

then becomes fairly constant at a value around 10 cm./sec. per volt/cm. Loeb[49] calculated from Langevin's equation that the mobility of a charged nitrogen molecule at atmospheric pressure would be 9.85 cm./sec. per volt/cm. The value here found is a surprisingly good check of this predicted value. The error is much below the probable error in our values of the mobility.

No explanation can be offered of the lower values found for the larger wire. It must be borne in mind, however, that there are several approximations underlying these calculations. The most serious of these are (a) the fact that a sine wave voltage was assumed for the calculations whereas the oscillograms showed a ratio of maximum to effective value of 1.52; (b) the fact that an electrostatic distribution of gradient has been assumed for the calculations, whereas the actual gradient differs far from that when the voltage rises considerably above the corona value, as will be shown later. Both of these errors, however, would cause the calculated value of the mobility to be lower than the value actually possessed by the ions. The lowered values for the large wire cannot be considered as due to a greater humidity on the day when this run was taken for the humidity was somewhat less that day than for the day when the values were determined for the small wires. The effect of the humidity could not be studied because there was no means of controlling the humidity and the normal variations in the room were not great.

A few measurements were made with 40 and 80 cycles to determine the aging of the ions but any variation due to this cause was masked by the variation due to the voltage increase above corona.

The sharp rise in the mobility curve for the positive ions just above the voltage for negative corona suggests that the ions, as they become much more copious are washing out some impurity from the air, such as moisture; and that when there are enough ions to wash out the impurity, the remaining ions travel as molecules. If we calculate the current necessary to carry out all of the water molecules in a cylinder of one-cm. radius around the wire, assuming a vapor pressure for the water vapor of 7.6 mm. of mercury, that each molecule requires one electronic charge, and that the water vapor must be carried out each half cycle, we find that a current of the order of 10. amperes per cm. length of wire would be required. If the water vapor is carried out, it must be a process extending over a number of cycles, but even this does not seem probable.

The curves for the mobility of negative ions do not show a sharp break as found for the positive ions. The curves, however, continue to rise more steeply than the curves for positive ions and there seems less evidence of a final maximum value. This is to be expected as the mobility of an electron, as predicted by Loeb[47], for atmospheric pressure is of the order of 1500 cm./sec. per volt/cm. The electrons evidently do not travel a very great portion of their paths before attaching to form ions, even in the high field around a corona wire. This is to be expected from the work done on electrons in moist air at low pressures.

At a voltage practically twice the corona voltage, the

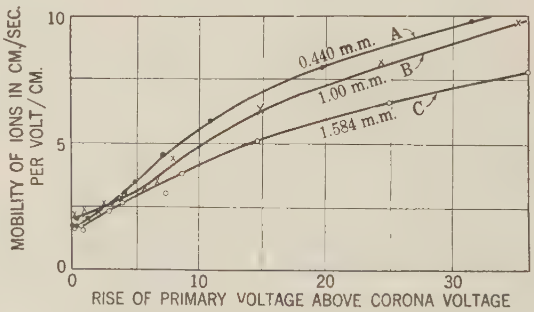

Fig. 17—Mobility of Negative Ions

A—Barometer 75.5 cm., Temperature 23.3-24.5 deg. cent., Humidity 8.6 mm. Hg.
B—Barometer 76.9 cm., Temperature 17.8-20 deg. cent.
C—Barometer 76.2 cm., Temperature 17.6-23 deg. cent., Humidity 7.4 mm. Hg.

mobility of the positive and negative ions are the same around 10 cm./sec. per volt/cm. as calculated from the boundary of the space charge.

12. Theory of Corona Current

In explaining corona on the basis of ionization by collision, it must not be assumed that ionization by collision starts at the corona voltage or that it starts so sharply as does corona. An inspection of the saturation curves of air around the corona voltage shows that

ionization by collision is present below the corona voltage. The corona voltage is determined rather by the condition that the ionization by collision has become cumulative in such a way as to lead to an unstable condition.

This may be illustrated by assuming that the potential gradient around the wire draws to the wire ions due to the ambient ionization of the atmosphere. As these ions pass through the layer in which corona will form, some of the ions will cause ionization by collision if the potential gradient is sufficiently high. Also some of these newly formed ions due to the ionization by collision, in their turn, will produce further ionization by collision, and any group of ions will tend, in this way, to reproduce itself indefinitely.

If, however, the new ions formed by any group are less numerous than the original group, the descendants of this group will soon disappear and the current will be approximately the saturation current of the air. On the other hand, if the new ions formed by any group are more numerous than the original group, the descendants of this group will increase indefinitely and the saturation current of the air will be similarly magnified.

This serves to show that a small increase in the gradient just at the corona voltage would lead to an infinite current or a short-circuit condition; provided the gradient remained at the increased value. (The exposition of the current given above is not rigid because of the assumptions for the average value. The rigid treatment given by Towsend,[9] however, shows the same characteristics for the current but in more complicated mathematical language.) In the case of corona, the gradient does not remain constant at the wire when ionization begins, for the space charge driven out from the wire increases the gradient at a distance from the wire where the gradient is low. Thus the space charge absorbs a part of the impressed voltage when ionization is taking place.

The conditions of equilibrium for a wire and concentric cylinder in the case of corona are; first, that the surface charge on the wire does not increase above the value which it attains when corona begins to form; second, that the space charge absorbs any rise in voltage above the corona voltage by raising the electric gradient at a distance from the wire. The space charge is composed of two charges, one returning to the wire, which was formed on the previous half-wave, and another, in process of formation and moving out from the wire. Under these conditions, the equation for the current is given in eq. (**13**) below where a is the radius of the wire, b, the radius of the cylinder, Q' is the space charge in process of formation, L' the radius of the equivalent cylinder of the space charge Q', Q'' is the returning space charge, and L'', its equivalent radius. (The equivalent radius of the space charge denotes the radius of the cylinder on which the entire space charge could be concentrated and absorb the same part of the impressed voltage that the actual distribution does.) V represents the maximum value of the impressed voltage and $w\,t$ has its accustomed significance.

$$i = \frac{1}{2 \operatorname{Log} b/a}\left(\frac{2\,Q'}{L'}\,\frac{d\,L'}{d\,t} - \frac{2\,Q''}{L''}\,\frac{d\,L''}{d\,t} + w\,V \cos w\,t\right) \qquad (\mathbf{13})$$

A solution of this equation, when the proper values are substituted for the Q's and L's, seems at present impossible. Some information about the corona current, can be obtained, however, from a discussion of the different terms.

The first term in the expression for the corona current, namely:

$$\frac{Q'}{L' \log\ b/a} \times \frac{d\,L'}{d\,t}$$

represents the rate at which new space charge must be formed to compensate for the outward movement of the space charge already formed. This term does not change sign during a given voltage half wave and is of the same sign as the voltage half wave.

The second term in the expression for the corona current,

$$\frac{Q''}{L'' \log\ b/a} \times \frac{d\,L''}{d\,t}$$

represents the rate at which space charge must be formed to compensate for the return motion of the space charge formed on the previous voltage half wave. The motion of this charge is opposite to that of the outgoing charge so that the current required by this term is in the same direction as that required by the previous term and these two terms add their effects as shown by the negative sign before this term.

The third term in the expression for the current

$$\frac{w\,V \cos w\,t}{2 \operatorname{Log} b/a}$$

represents the current due to variation in the impressed voltage, and is the current due to electrostatic capacity. This term is of the same sign as the voltage wave on the rising part of the wave but reverses in sign at the crest of the voltage wave.

Approximate Formula for Corona Current

As seen above, an exact solution of eq. (**13**) for the corona current seems impossible. An approximate solution may be obtained however, by assuming that all of the space charge is formed previous to the crest of the voltage wave and that it is just sufficient to support the rise in voltage above the corona voltage at the crest of the voltage wave. In order to make the calculations possible, we have assumed also that the returning space charge is canceled (in recombination) by the first half of the new space charge formed, and that the remainder of the new space charge, at the crest of the

voltage wave, is concentrated on a cylinder of radius L'. The method of calculation L' is empirical, however the function used was suggested from theoretical considerations, as will be seen in the complete paper.

As shown above, the surface charge per unit length of the corona wire never exceeds the value q', which it attains just at the corona voltage V'. Any increase in the voltage causes ionization and the formation of a space charge around the wire which absorbs the excess of the voltage above the corona value.

If we measure the current into the wire from zero voltage up to a voltage above the corona voltage, we observe a current relation as shown in Fig. 19. There is a sharp break in the current curve at the corona voltage V'. At any voltage V above the corona voltage, the current may be resolved into two parts; I' a constant part due to the surface charge on the wire and I due to

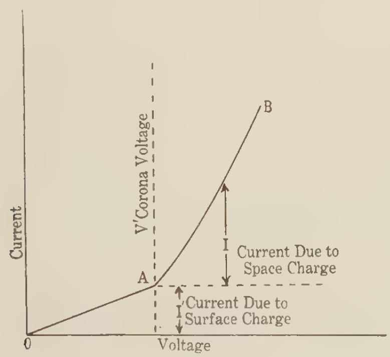

FIG. 19

the space charge around the wire. This part due to the space charge we will call the corona current.

The formula for this corona current is then

$$I_{av} = \frac{f\,l\,(V'' - V')}{4.5 \log b/l'} \times 10^{-11} \qquad \textbf{(19)}$$

and L' has the value

$$L' = \sqrt{\frac{1}{\pi f \log b/a}} \sqrt[4]{V''^2 - V'^2} \qquad \textbf{(20)}$$

I_{av} = average value of the corona current in amperes
f = frequency in cycles per second
l = length of the corona wire in cm.
V'' = maximum value of the impressed voltage in volts
V' = maximum value of the corona voltage in volts
b = radius of outer cylinder in cm.
a = radius of corona wire in cm.

In order to apply this to a two wire transmission line we have the following changes:

V'' = maximum value of impressed voltage to mid-point between wires (ground)
b = distance between wires, in cm.

This formula is not applicable unless all of the space charge formed on one half wave returns on the next. When a wire and concentric cylinder are used, the cylinder should be so large that the space charge does not reach the cylinder. The size of cylinder required of course depends on the frequency, size of wire, and the rise of the voltage above the corona voltage. The radius required in any case can be determined by calculating the distance traveled on any half-wave, by the ions formed just as the instantaneous voltage reaches the corona voltage. This distance may be calculated

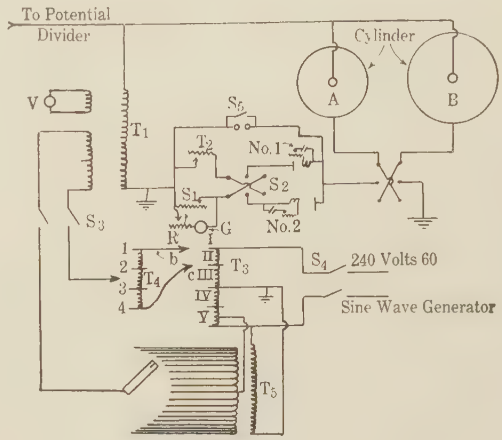

FIG. 22

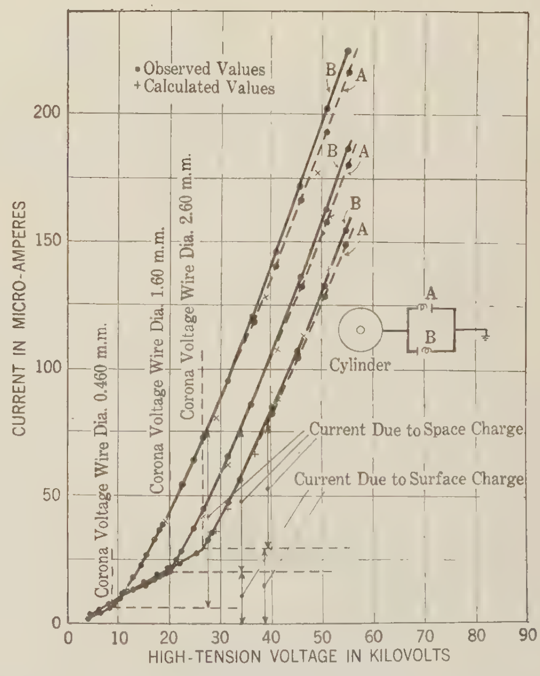

FIG. 23—CORONA CURRENT CURVES. AVERAGE VALUE OF HALF-WAVES. DIAMETER CYLINDER 61 CM. ACTIVE LENGTH OF WIRE 62 CM. FREQUENCY 64 CYCLES.

by assuming the ions to have a mobility of 10 cm./sec. per volt/cm. For 60 cycles on a No. 10 wire with a voltage twice the corona voltage the radius of the cylinders should be about 30 cm. This was checked experimentally.

MEASUREMENT OF CORONA CURRENTS

Corona currents were measured in two large cylinders by rectifying the charging current to a central section of the cylinder through three electrode vacuum tubes

with grid connected to plate. The current was measured by a calibrated D'Arsonval galvanometer which could be connected to measure either the positive or negative half waves. A diagram of connections is shown in Fig. 22.

Cylinder *A* was 61 cm. inside diameter and composed of a central section 62 cm. long and guard rings on each end of approximately the same length. The central section in which the current was measured was screened from stray fields by a gauze wire around the outside. Cylinder *B* was 155 cm. in diameter and composed of a central section and two guard rings each 154 cm. long. The central section of this cylinder was also screened from stray fields.

The charging current of the central section of each cylinder was measured for three sizes of wire, up to a voltage at least twice the corona voltage. These values are shown in Figs. 23 and 24. The currents plotted are rectified half waves, and therefore represent half of the total current expressed in average values.

The readings of the positive and negative half waves were equal except when the space charge began to reach the cylinder. The symmetry of the current waves is no indication that the positive and negative space charges are equal because any half wave measures the outgoing charge of one sign and the returning charge of the opposite sign. This is not true when the cylinder is small. With small distances between the wire and cylinder the current corresponding to the formation of negative space charge exceeds the current corresponding to the formation of positive space charge. This may be explained as due to a decrease in the return of negative space charge, and as the voltage corresponds to that at which the negative charge should reach the cylinder it seems most probable that this difference is due to a decrease in the return of negative space charge. This indicates that the negative space charge reaches the cylinder first, which is also in accord with our previous measurements of the mobility of the negative space charge for it was found that around twice the corona voltage the mobility of the negative space charge passed the mobility of the positive space charge. For the large cylinder it was not possible to raise the voltage to such a value that the positive and negative current half waves became unequal.

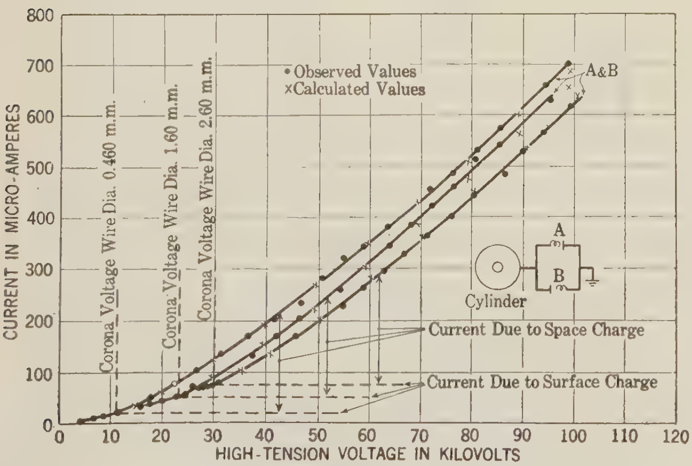

Fig. 24—Corona Current Curves. Average Value of Half-Waves. Diameter of Cylinder 155 Cm. Effective Length of Wire 154 Cm. Frequency 64 Cycles

Calculation of Corona Currents

The corona currents are calculated for each case in which the current was measured, and the calculated values are shown on the curves by crosses. The agreement between the calculated and observed values is in every case quite satisfactory.

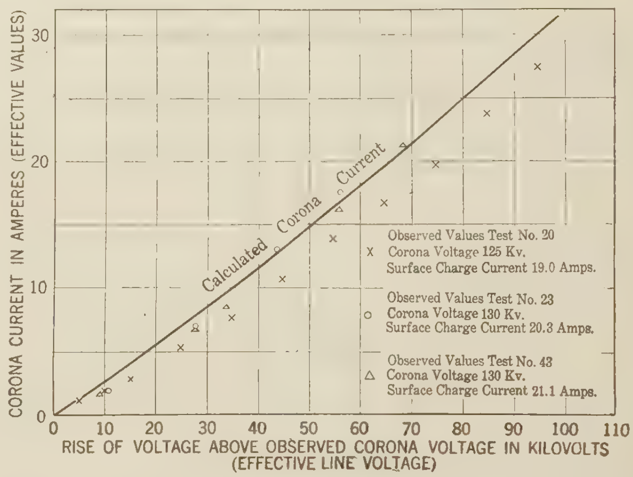

Fig. 25—Corona Current Calculation. Tests of W. W. Lewis, A. I. E. E. Trans., Vol. 40, p. 1059. Three Phase Line Wires in Vertical Plane. Length 101.5 Mi. Spacing 12 Ft. Conductors No. 0, Seven Strand. Diameter 0.19 In. Frequency 30 Cycles

The corona currents are also calculated for the three-phase transmission line studied by W. W. Lewis[37]. This line consisted of three 110,000-cm., seven-strand conductors, spaced 12 ft. in a vertical plane. The length was 101.5 mi., and the radius of the conductors was 0.19 in. The corona voltage is here determined by the break in the charging current curve given by Lewis. In calculating the corona current, voltages to neutral are employed. The measured currents are in effective amperes. In order to convert the corona current from average to effective values the factor 1.11 is used. (The ratio for a sine wave). This is open to criticism but no better method presented itself. A comparison of the observed and calculated values for this transmission line is given in Fig. 25.

The agreement is surprising when we consider the possible causes for discrepancy. Among these causes may be mentioned (1) the fact that the voltage rose about 10 per cent along the line so that different parts of the line were at different stages of corona formation, (2) the space charge around the wire with corona on it distorted the electric field and therefore the neutral of the system. (This may cause a shift of the voltage

away from the corona wire), (3) the ratio of the effective to the average value of the current is probably not 1.11 as assumed, (4) the frequency of these tests was 30 cycles while the formula for corona current was developed for 60 cycles.

15. Summary

1. The spectrum of corona shows the band spectrum of nitrogen indicating that only the nitrogen breaks down in a corona discharge in air and that the ionization produces electrons and positively charged nitrogen molecules rather than a dissociation of nitrogen molecules into atoms. The electrons, even in the high electric field around corona wires, almost immediately attach themselves to molecules, (probably of water vapor or oxygen) forming ions as seen from the mobility below.

2. The air was rendered more conducting by a quartz mercury arc and the saturation current measured as the voltage approached the corona voltage. The corona voltage lies somewhat above the first rise of the saturation current due to ionization by collision. Saturation curves taken on copper and magnesium wires show no influence due to the material of the conductor. This indicates that the positive ions are active ionizing agents as Towsend has assumed.

3. Corona forms on the positive half waves of an alternating impressed voltage about 2 per cent below the voltage required to form corona on the negative half waves. (This has been tested only at atmospheric pressure for wires between No. 25 and No. 10 B. & S. gage). The first appearance of positive corona does not give appreciable sound nor light, and ions due to this corona do not penetrate the air to a distance greater than about 8 cm. (for No. 10 wire at atmospheric pressure).

4. The amount of ionization on the positive half wave becomes very much more copious with the appearance of corona on the negative half waves.

5. The observed voltage for positive corona was found to be much less subject to errors due to surface irregularities and the divergence of the field, than the observed voltage for negative corona. This is to be expected from similar work on the continuous corona.

6. The ions formed around a corona wire during any half wave, which are of the same sign as the potential of the wire, are driven out from the wire forming a space charge. This space charge moves out from the wire until the voltage reverses. It then returns to the wire. Thus the space charge is able to penetrate the air around the wire only to a definite distance, or may be said to have a boundary. This boundary of the space charge varies with the corona voltage, the rise in voltage above the corona voltage, and the frequency. Diffusion reduces the sharpness of the boundary of the space charge. (See Figs. 14 and 15).

Since the space charge formed on any half wave returns to the wire on the next succeeding half wave, we must consider, during a half wave, two approximately equal space charges; one space charge of the same sign as the potential on the wire traveling out and the other space charge of the opposite sign to the instantaneous potential of the wire and returning.

7. The mobility of the ions formed in the corona discharge were calculated from the boundaries of the space charges. The mobility of the positive ions was found to increase with the rise of the voltage above the corona voltage from about 1.3 to 10 cm./sec. per volt/cm. The mobility of the negative ions was found to rise with the increase of the voltage above the corona voltage from about 1.6 to 10 cm./sec. per volt/cm.

The curves of mobility of positive ions plotted against rise in voltage above the corona voltage indicate a limiting value of the mobility of about 10 cm./sec. per volt/cm. This is in good agreement with the value 9.85 calculated by Loeb[49] from Langevin's equation. The curves for the mobility of negative ions do not indicate that a limiting maximum value is probable.

8. An analysis of the conditions of corona formation indicate that the gradient near the surface of the wire can never rise above the value it has at the corona voltage. This requires that the surface charge on the wire be constant for all voltages above the corona voltage and that the space charge support any rise in the voltage above the corona voltage. The differential equation of the corona current based on these conditions does not admit of a simple solution.

9. An approximate formula for the average current due to the space charge has been derived by the aid of certain empirical assumptions. This formula gives a good agreement for the corona currents measured in two large concentric cylinders. The corona currents were calculated by this formula for 101.5 mi. three-phase transmission line and the agreement is reasonable, with the measurements made on this line by W. W. Lewis.[37]

The author wishes to express his appreciation of the facilities provided by The Johns Hopkins University, and the assistance given by members of the faculty. He is particularly indebted to Dean. J. B. Whitehead for his valuable suggestions and criticisms, and to Dr. W. B. Kouwenhoven for his advice on problems of measurement. The author also wishes to express his appreciation of the assistance given by Mr. S. K. Waldorf, graduate student in engineering, in the measurement of corona current.

BUOY LAMPS

During two years' service in a five-mile stretch of the New York State Barge Canal at Utica, electric buoy lamps have shown that they cost $15 a year as compared with $65 for oil lamps which need inspection and attention daily. Fewer electrics are needed because they are brighter.

Discussion at Pacific Coast Convention

THE SPACE CHARGE THAT SURROUNDS A CONDUCTOR IN CORONA AT 60 CYCLES[1]

(Ryan and Carroll)

Salt Lake City, Utah, September 6, 1926

H. E. Mendenhall: I should like to ask Mr. Carroll one question. Two years ago, Professor Sorenson discussed Doctor Ryan's paper and he had a theory that this corona loss might be caused by the positive ions not traveling as far as the negative ions. I should like to ask if they were able to determine whether or not the space charge is out further when it is negative than it is when positive?

F. O. McMillan: On account of the negative corona forming in tufts on the conductor as shown with the stroboscope by observation of a conductor in a-c. corona, one would expect that the space charge established during the negative half cycle would also be tufted and not uniformly distributed along the conductor. If this is true then a parallel potential exploring wire such as the one used by Doctor Ryan and Mr. Carroll, would indicate a mean negative space-charge potential smaller in value and located nearer the conductor than the actual tufted space charge. Do the authors consider the diffusion of the space charge to be so great that the distribution of the negative charge is uniform along the conductor?

C. H. Willis (communicated after adjournment): The density of the space charge and the distortion which it produces on the electrostatic field of the conductors, is an exceedingly difficult problem. The method developed by the authors is a very ingenuous attack upon this problem. I think, however, that their method is subject to the following criticisms.

First, the authors assume that their test wire attains the potential of the surrounding space when bombarded by a cloud of ions just as it does when the surrounding air is an almost perfect insulator. It has been found in a number of instances that a test electrode of this type in the presence of an ionic stream accumulates a charge which distorts the electric field around the electrode. This may be a source of considerable error here.

Second, the authors assume that their test electrode follows the potential of the surrounding space with no time lag and therefore in phase with the electric field of the space around the test wire. If this test wire has appreciable capacity to ground or leakage, this assumption would not be justified, since the test wire at times is several hundred volts above ground.

In Fig. 4 the authors show that one curve is "located by commonly accepted theory, on the assumption that the entire space charge is uniformly distributed about the conductor at the radial distance, 2.67 in.." In that case, this curve should be a portion of a rectangular hyperbola, but the curves given do not appear to be such.

It seems quite surprising that the maximum shown in the curves of Fig. 4 should shift only 0.23 in. in the quarter period following the crest of the voltage wave, and this is particularly unexpected when the center of the space charge layer is found 2.67 in. from the wire almost immediately upon formation; that is, at the crest of the wave.

In some work done at Johns Hopkins University, which I hope will be published soon, the mobility of the ions in the corona space charge was found to be around 7 cm./sec. per volt/cm. In view of this mobility of the ions it seems much more probable that the maximum found in the curves of Fig. 4 represents the inner boundary of the space-charge layer at the instant the impressed voltage passes through zero, or at the instant when the space-charge layer is farthest from the axis of the corona wire. This would indicate that the free charge picked up by the test electrode is the principal factor in the results of this paper.

1. A. I. E. E. Journal, November 1926, p. 1136.

Jos. S. Carroll and Harris J. Ryan: Replying to Mr. Mendenhall's question: Were we able to determine whether the space charge is or is not further out when negative than when positive? Our results indicate that the difference could not have been very great. We have charted, in rectangular coordinates, the potential-radius relations by means of the requisite values taken from the curves of Fig. 8 at those phases of the cycle wherein the positive and negative voltage crests were just beginning or ending and again when the voltage was zero. As stated in our paper, the point of discontinuity in the potential-radius relation was taken in each case as determining the radial distance to the center of the cylindrical space charge. The results thus obtained are given in the following table:

SPACE CHARGE COMPLETE

Phase (deg.)	Radius (in.)	Condition
40	2.5	+ initial
90	2.9	+ central
140	2.6	+ final
220	2.8	− initial
270	3.0	− central
320	2.5	− final

We hardly feel that much significance can be attached to these radial differences more especially because of the presence of the widely distributed positive space charge caused by the rectifying effect of the conductor and cylinder. When the conductor was positive, the charge due to rectification was repelled by the conductor and the newly formed positive space charge. Such action may well have diminished the radius at the 40-deg. instant with respect to what it might have been in the absence of such charge due to rectification. Again, the converse should be true at the 220-deg. instant when the negative voltage crest had just completed the corresponding negative space charge. Such space charge may have been attracted by the positive charge due to rectification and its radius thus been made greater than would have been the case if the charge due to rectification had not been present. The action being cyclic, one would expect the charge due to rectification to be in its central position when the voltage was zero and that at such instant it would have little or no effect upon the value of the space-charge radius. The corresponding radii for the positive and negative space charges at the zero-voltage instants of 90 and 270 deg. were 2.9 and 3.0 in. respectively.

Mr. McMillan asks: "Do the authors consider the diffusion of the negative space charge to be so great that the distribution of the negative space charge is uniform along the conductor?" For the conductor and voltage used—yes. The voltage used was substantially sufficient to maintain a fixed brush pattern and therefore sufficient to sustain full corona. Had the voltage been just sufficient to begin the formation of one or more brushes in an unstable pattern, the brushes might have been too far apart to form a complete and reasonably complete space-charge cylinder. In that event the wire would have been a form of potential exploring electrode that would have been unsuited for the purpose. When the brushes are too far apart to maintain continuous space charges along the conductor the study would have to be applied to individual brushes and the radial distances to the space charges they set up. When such studies for individual brushes are made, it seems reasonable to us to expect that the radial distance will be found very much the same as for fixed brush patterns. We base this expectation on the fact that approximately 10,000 volts per in., sine-wave effective, are required to produce flashovers, alike for parallel conductors of any size that develop local or full corona in advance of flashover and between pointed conductors in opposing alignment.

Mr. Willis apparently has not made a study of the related papers that preceded the present one[4,5]. In those papers the existence of the space charge that surrounds a conductor in corona was authenticated. It was shown to be the major factor in determining the value of the power loss due to corona. Its cyclic character was observed in a large number of cases. Indirectly its radial distance from the conductor in corona was determined.

When the use of the potential exploring wire was begun, it was largely for the purpose of checking the understanding already gained of the position and cyclic character of the space charge. The difficulties stated by Mr. Willis were anticipated when the work was planned. Some of them were encountered early in the work and the strategy was modified, step by step, until consistent results that checked reasonably well with the known facts were obtained. By test, the insulation of the exploring potential wire-assembly was maintained amply high. By trial in the final set-up, the capacitance of that part of the assembly that extended beyond the corona-forming field was amply low. The conductor and cylinder acted as a limited rectifier and thus constantly maintained a widely diffused positive space charge. To see if the positive charge collecting on the exploring wire would alter the space-charge wave a negative potential was maintained on the exploring wire by means of a kenotron and a very high resistance. The space-charge curve showed only a slight change in form. Various other tests were made, all of which showed that the exploring wire was giving the potential of the space it was in sufficiently accurately for the work.

Regarding the potential curve in Fig. 4 "located by commonly accepted theory," Mr. Willis says "this curve should be a portion of a rectangular hyperbola but the curves given do not appear to be such." Of course not. Charges on concentric cylinders give rise to electrical intensity—radius relations that mathematically speaking are *hyperbolic*, and to potential—radius relations that are logarithmic. As clearly stated, the V series of calculated curves in Fig. 4 are potential curves. They are therefore logarithmic and not hyperbolic.

In conclusion Mr. Willis is apparently convinced that he has found that "the mobility of the ions in the corona space charge was around 7 cm./sec. per volt/cm." and on the basis of that, argues that "the free charge picked up by the test electrode is the principle factor in the results of this (our) paper." To that we reply that the *E-Q* cyclogram is an established fact. It asserts that there must be more than one mobility of the ions in the cyclic production of the space charge,—perhaps a number of mobilities.

ELECTRICITY AND COAL MINING[1]

(Harrington)

Salt Lake City, Utah, September 7, 1926

F. L. Stone: Mr. Harrington is to be congratulated on the excellent way in which he has presented to the electrical engineers the very serious problem of mine electrification. It is very evident from Mr. Harrington's description of the conditions that electrification of mines must go on and mining machinery must be electrically driven; otherwise mining costs would be prohibitive.

The figures quoted by Mr. Harrington regarding the increasing percentage of explosions due to faulty electrification cannot be lightly swept aside. These figures, I take it, have been gathered from government reports and consequently must be accepted as fairly reliable. To explain why the percentages of electrical accidents are increasing does no particular good—the fact remains, as pointed out by Mr. Harrington, that they *are* increasing, which is the all important fact. It is all very well to say that as more and more mines become electrified we must expect more accidents attributable to electrical devices. The figures given by Mr. Harrington indicate something else as well; that is, that the old and most frequent causes of explosions, such as open lamps, careless use of matches, etc., are becoming scarcer. These hazards are things which the ordinary mine foreman can understand and guard against; but, as Mr. Harrington states, these men are usually almost helpless to decide whether a certain piece of electrical apparatus or wiring is safe or dangerous.

I do not feel that so large a percentage of the blame should rest on the electrical engineers as that with which Mr. Harrington would credit us. The electrical engineer or salesman visits a coal mine of an operator who has asked for a motor to do a certain piece of work, and the salesman questions the advisability of installing this motor, as in the presence of gas, it will undoubtedly cause an explosion. The mine operator advises him that there is no danger, as he intends to keep his ventilation to such a point that there will never be an explosive mixture in the vicinity of this motor. While the salesman may know, in his heart, that even though the mine operator feels the statement to be true, there are many contingencies to arise which would completely upset the calculations in regard to ventilation, such as the falling of the roof, fan stoppage, etc. After such an answer, the salesman is comparatively helpless and I do not feel that he is to be seriously censured if he endeavors to take the order under the conditions outlined by the operator.

Personally, I am inclined to believe that no open motor or unapproved motor is safe when operating at the working face. Even in my limited experience, I have seen gas feeders tapped in most unexpected places, these feeders sometimes giving off enormous quantities of gas.

Coal mining under the best of conditions is a hazardous occupation, and I am sure the electrical engineers and the larger manufacturers are heartily in accord with Mr. Harrington in his plea for safety.

On the other hand, however, to my mind, the greatest danger lies not so much in the apparatus as in the slipshod and careless way some of this apparatus is wired, particularly apparatus which might be styled "portable," such as gathering pumps, individual room fans, etc. Here the problem is clearly up to the mine electrician and mine management and, finally, to the state mine inspection bureau. The mine inspectors, as a rule, are thoroughly competent in regard to practically all subjects connected with mining except electrification, and here many of them are woefully lacking in regard to essential details.

In further defense of the electrical engineering fraternity, I should like to advise that for many years a committee has been working on a report entitled "Suggested Safety Rules for Installing and Using Electrical Equipment in Coal Mines." This committee is sponsored by the American Mining Congress and the Bureau of Mines. The membership of this committee was drawn from all classes of electrical engineers interested in any way in mine electrification. The result of the committee's efforts is that their report and recommendations is today before the American Engineering Standards Committee for final approval, and, as nearly as can be predicted, this report will be an American standard within a very short time.

If the recommendations set forth in this report are followed, I believe a large percentage of accidents due to mine electrification will disappear. In order for them to be followed, however, I very much fear it will require state legislation, making it imperative that the most up-to-date apparatus and installations generally be used.

P. M. Downing: Mr. Harrington condemns the use of electricity in mines, not because it is an unsatisfactory agent for such use but because the installation is not properly made, and because of this improper installation, accidents occur. Perhaps if the installations were made properly, there would be fewer accidents and I do not think that electricity can be condemned simply because improper use of it has been made in the coal mines.

1. A. I. E. E. Journal, December 1926, p. 1264.

D. C. McKeehan: Mr. Harrington has endeavored to bring out the psychological points, and, from the statistics, has a strong indictment against the use of electricity in coal mines.

The outstanding feature and one of the greatest short-comings of coal-mining work is that the rules and regulations are "more honored in the breach than the observance."

The first thing to be done in connection with the use of electricity in coal mines is to put the "house in order" by providing proper ventilation, rock dusting, installation of rock-dust barriers, sprinkling, electric safety lamps and the enforcement of rules that we know from experience cannot be violated. The adoption of these safety measures will limit the damage in case of an explosion and electricity will not be accountable for such holocausts as we have experienced.

The use of electrical machinery at a face not normally subject to gas may be quite safe; failures of the ventilation system, however, or caves may cause accumulation of dust or gas so that it behooves the operator to use nothing but permissible apparatus. If the ventilation is adequate, no hazard exists in the so called non-gaseous mine.

The practise of sprinkling the mines makes an ever increasing hazard due to electric shock from contact with the apparatus or conductors. Insulation failures in approved machines may permit of a spark from the machine frame to moist earth, pipe lines and track, and may consequently become dangerous and stir up trouble.

The matter of effectively grounding all parts that may have a potential greater than that of the earth should be closely watched.

The equipment in the mines should be handled by persons whose competency is unquestioned.

TRANSMISSION FEATURES OF TRANSCONTINENTAL TELEPHONY[1]

(Nance and Jacobs)

Salt Lake City, Utah, September 9, 1926

J. E. Heller: It might be of interest to point out some applications in the West of the developments described by Mr. Jacobs. The longest circuits in the West include those from San Francisco to Seattle, Denver and Salt Lake City. The Seattle circuits are about 950 mi. in length and are made up of carrier channels to Portland, open wire from Portland to Tacoma and cable from Tacoma to Seattle. A large portion of the toll-circuit relief during 1927 in the Pacific System will be cared for by means of about 10 telephone carrier systems. In the next few weeks an additional circuit consisting of 104 wires will be established between Salt Lake City and San Francisco. This circuit, from a service standpoint, will be practically equivalent to the 165 circuits between San Francisco and Chicago.

Mr. Jacobs mentioned improvements in the quality of the transmission due to better transmission-frequency and impedance-frequency characteristics of repeaters and associated equipment. Quality consists of two components, namely; volume and intelligibility. The volume is a function of the energy transmitted, while intelligibility is a function of the band of frequencies transmitted. The New York—San Francisco connection has a volume equivalent of about 12 T. U. and will transmit frequencies between 300 and 2600 cycles. While it would be possible to increase the volume equivalent and, at the same time, increase the band width above 2600 cycles without materially affecting the quality, the choice of volume equivalent and band width is dictated by the economics of the situation.

In order to stimulate interest in the use of the transcontinental service, public demonstrations were held during 1915 at which a large number of people listened to selected programs transmitted over the transcontinental circuits. These demonstrations were accepted as more or less of a novelty by the majority, who did not give serious consideration to the use of the service. Later, smaller and selected groups were brought together at both ends of the line and members of each group were allowed to talk to friends at the other end of the line while the rest of the group listened. These demonstrations were very successful in showing the practicability of the long-distance service, as is indicated by the growth of the business.

K. B. Miller: The present telephone instruments, transmitter and receiver, are something like 32,000 times more efficient in the air-to-air transmission than was Bell's original centennial experiment which caused such astonishment fifty years ago. That 32,000 times more efficient instrument that we have now does not take into account any difference in the lines. To show what these men have done to the line in the way of improving its efficiency, we have only to recollect that an exact replica of Bell's instrument was used in transcontinental conversation in 1915, so that the difference involves something like a 32,000 ratio (representing the efficiencies of the two instruments) which was overcome entirely by the improvements in the line (by line I mean transmission system between the two terminal points). Looking at it in another way, in order to get the requisite amount of energy from San Francisco to New York without these improved instruments in the line would require enough energy put into the line to annihilate the line absolutely; vaporize it, in fact, in order to get the required amount of energy across the continent. I think those illustrations will show something of what has been done; in fact, the whole tendency lately has been to decrease the conductivity of the line, thus accomplishing very much credit in the amount of copper saved by use of repeaters, loading coils, and similar improvements.

W. G. Rubel: It might be interesting to add that we have a great many circuits throughout the United States which are very similar in type to the ones described, and while not normally employed to connect, directly, points as widely separated as those mentioned, they may be used as sections of built-up long-haul circuits by connecting them together and inserting telephone repeaters at proper intervals. These long built-up circuits are equivalent approximately to the direct transcontinental type circuits, and when once established, the service over them is of high grade. In the case of such circuits an appreciable time is required to build them up and a very large number of pieces of auxiliary apparatus is involved in signaling, in adjusting repeater gains, etc., while establishing through connections.

An ideal arrangement, from the standpoint of traffic at least would be to have direct circuits from any point to every other point in the country; that is, of course, economically impracticable. That is the trend in the design of circuit layout, however, and we find that when the community of interest between any two localities is such as to indicate the necessity of a direct circuit, such a circuit is provided so that in addition to the long direct circuits discussed in this paper we have a network of shorter circuits radiating from every important center in the country. For example, from Salt Lake City, there are 35 direct toll circuits varying in length from a few miles to 600 or 700 mi. One of these is to Pocatello, Idaho, where a connection may be made through a repeater to a circuit extending from Pocatello to Boise. From Boise, this circuit can be extended to Baker, Oregon, and from there to Spokane, Portland, Seattle and all of the Pacific northwest. We can also build up a circuit from Salt Lake City through Pocatello north to Canadian points, which may in turn be connected either to the East or West at Salt Lake City.

It is by means of circuits of the type discussed in the paper, supplemented by the shorter but none the less important toll circuits, that universal telephone service is now being realized in the Bell System.

1. A. I. E. E. Journal, November 1926, p. 1061.

Discussion at New York Meeting

REMOTE CONTROL OF MULTIPLE STREET LIGHTING[1]

(Dempsey)

New York, N. Y., November 12, 1926

A. H. Kehoe: There are a number of systems using the multiple type of street lamp, but the advantages of controlling them by relay has not been generally realized. The subject was intensively studied by the companies supplying Manhattan Island in 1918. Early in 1920 the United Electric Light and Power Company had completely equipped all of its street lamps for relay control of a type as indicated in the paper. This system uses an a-c. relay at every lamp except in the case of park lighting, where an installation's only purpose is for street lighting. With this system, the reliability in operation is very good as a relay failure affects but one lamp.

Several facts were deduced from the cost of making this installation. We found that the relay is not the important element in the cost. The relay used will operate with the smallest conductor which we considered it desirable to use from the standpoint of mechanical strength, this being a lead-covered No. 12 B&S gage. If relays can be made to operate without a special conductor, it will be possible to make a still cheaper installation and yet pay considerably more for the relays. The series system so commonly used requires a large, well insulated conductor, which makes its cost higher than a multiple-controlled system, provided there is to be other load in the same area; if not, the choice between the two systems will depend upon the particular district to be supplied. The prevailing style of system, of course, has been the series system, and it is important to have the features of the relay-controlled multiple system widely broadcast. It is usually recognized that in densely loaded districts the multiple arrangement may be advantageous, but few realize that many of these advantages hold in the sparsely settled districts (which are now rapidly disappearing on Manhattan). For instance, there is the advantage that the pioneer who comes soon after the street lamps is able to get his service immediately, as it can be had from the street-lamp system.

The combination of all the electric requirements on the single set of mains is the advantage which I feel should be especially emphasized.

N. J. Kelly: In 1923, while the public clamored for the immediate installation of a traffic-control light system on Broadway to relieve the congestion of this heavily laden avenue, the Department of Water Supply, Gas & Electricity delivered some 19 ornamental heavy street-lighting standards to the Police Department, and designed a lamp housing which was attached to the mast arm and had manually-operated switches. These units were erected as a temporary expedient for traffic-control signals and installed on the sidewalks rather than in the street, proper. The idea was new to New York and worked so well that it was decided to "tie in" all units for automatic operation. At this stage, Mr. Dempsey introduced an automatic circuit which was in keeping with the circuit designed for the remote control of multiple street lighting, and met with such success as to be adopted as a standard where automatic signals are required in a d-c. territory.

In this city with its five boroughs comprising an aggregate area of 316 sq. mi., more than 99,000 street-lighting units provide ample illumination to 3400 mi. of streets, avenues and highways. It is therefore of the utmost importance that the control of these units, whether they connect to a multiple or series system, be such as to guarantee maximum service at a minimum cost, and in this Borough of Manhattan, where practically all street lighting is derived from an underground multiple system, trouble has been localized; but continuity of service, which is the governing factor, has been assured.

H. R. Searing: It may be interesting to give some operating results on the multiple street-lighting system of the United Electric Light & Power Company mentioned by Mr. Dempsey. The system has been in operation since 1920. The following table shows the small number of failures of the no-voltage relays to operate. The figures for the year 1925 and the year 1926 up to October 31, are,

GRAVITY-TYPE RELAY

(1242 in service in 1925; 1176 in 1926)

Operation	No. of Operations	Failures	
		Total No.	Per Cent
Drop—p. m.	847,334	83	0.0098
Pick up—a. m.	847,334	15	0.0018

SPRING-TYPE RELAY

(731 in service in 1925; 812 in 1926)

Operation	No. of Operations	Failures	
		Total No.	Per Cent
Drop—p. m.	513,663	29	0.0056
Pick up—a. m.	513,663	5	0.0010

These figures show that relay trouble is insignificant and does not compare with burned-out lamp trouble.

Mr. Dempsey did not point out that the system supply is alternating current and that the time switches which control the circuits are Warren clocks which require no winding.

W. H. Suydam: Local operating conditions dictate to a

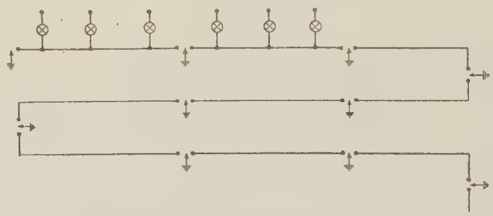

Fig. 1

large degree the type of control and distribution system best suited to a particular street-lighting problem. With low-tension a-c. networks as employed by some power companies, a low-tension multiple network system of street lighting seems to offer a reliable and economical solution. Each block of lamps with this arrangement would be fed as shown in the accompanying illustration.

The control for this type of system narrows down to a selection of either full automatic clock control or pilot control employing relays as described by Mr. Dempsey in his paper. A few desirable time switches which might be employed provided they were located in suitable subway tanks and located in transformer and distribution manholes, are: Sauter, States, Anderson and Warren motor. Of these the Warren motor type seems to show the greatest promise.

Carrier-current control has experienced considerable development during the past few years and may eventually provide a reliable and convenient means of controlling street lamps. The system above mentioned should lend itself readily for conversion to carrier-current control at some future date.

The pilot-wire system as described in Mr. Dempsey's paper is

1 A. I. E. E. Journal, January 1927, p. 12.

in my opinion simple and reliable. I prefer, however, to work toward extreme simplicity in distribution and total independence of neighboring control apparatus, provided suitable Warren motor clock switches can be obtained this would result in the elimination of the pilot wire.

The New York Company averages 5.3 lamps per control point which is probably due to their peculiar operating conditions. I believe that in connection with a low-tension a-c. network this number could be considerably increased.

It is generally recognized that it is desirable to have lamps go on rather than out in the event of pilot-wire trouble, however; it is also important that they become extinguished promptly at dawn, which would not be the case with the pilot wire until the source of trouble had been located and rectified. On the other hand with the clock method all but the particular circuit in trouble would be promptly extinguished. It might be well to note that every alternate clock switch might fail to function without resulting in lamp outage. Two adjacent switch failures would cause one group outage, while trouble with the pilot wire would affect all groups. An advantage often claimed for the pilot-wire arrangement is that it provides a means of checking the continuity of the circuit. While this may be true of the pilot wire, it does not appear that this check can be extended to apply to the relays and lamp circuits. In congested areas I believe the streets are patrolled nightly for lamp burnouts and at such times a defective clock switch would readily be discernible and promptly rectified. Furthermore, experience with Warren motor clocks will enable their further development, resulting in greater reliability. The Warren motor switches might be developed so that resetting could be accomplished without the removal of cover and switches mounted on stab contacts, permitting their ready removal, thus enabling clock substitutions in case of trouble and repairs effected at the shop.

O. F. Haas: The Cleveland Electric Illuminating Company serves some 600 multiple lamps in the residential district of the City of East Cleveland. The house-lighting distribution system is carried along the rear lot lines on wooden poles. The street-lighting feeders are brought down along the side of the pole to the ground and then carried underground along the side lot line to the street lamp at the curb. Time switches are used to turn the lamps on and off a number being controlled by each switch.

The Minneapolis General Electric Company has standardized on multiple street lighting for the City of Minneapolis, using a system quite similar except that the lamps are turned on and off by a control circuit. Until recently, however, series lamps, rather than multiple lamps, had been used on these multiple circuits. I should like to give just a word of caution in regard to this type of installation, without going into all the technical details involved, which may be obtained from the lamp companies. Where a multiple distribution system is used, multiple lamps should be employed and where a series distribution system is used, series lamps should be employed. Incandescent lamps are designed for a particular service and if they are not used in the manner for which they were designed, satisfactory service will not be obtained.

A new white way lighting installation has just recently been completed on State Street, Chicago. To my mind, one of the most remarkable things about this system is the fact that the Commonwealth Edison Company, by utilizing its duct lines and store-lighting feeders, was able to install what is by far the most outstanding white way lighting system in the country without tearing out any pavement or sidewalks. Approximately three times as much light is provided as on any other street in the world. Two thousand-watt, 4500-c.p. lamps, two per post, are used. The posts are located opposite each other and the energy consumption is 8 kw. every 90 ft. The resultant initial illumination on the street is over 4 foot-candles—a higher level of illumination than obtains in many stores and offices.

L. G. Smith (communicated after adjournment): There is one point which I feel has not been sufficiently stressed. I refer to the subject of maintenance costs, assuming that time switches, relays for use with pilot-wire systems, and Warren-clock time switches, etc., are all equally reliable. There is yet another comparison that should be made in addition to the first costs of the control system; that is, the effect of maintenance costs. In order to keep maintenance costs at a minimum, the control apparatus used should be as simple as possible, because, as a rule, the more complicated a mechanism, the more attention maintenance will require. For this reason, a sturdy relay, simple in design and as fool-proof as possible, would require considerably less maintenance than a time switch.

Moreover, in any multiple system, the essential characteristic of design will be to keep the multiple circuits as short as possible. This necessitates the use of a large number of individual control mechanisms. If time switches are used for each individual circuit, an enormous quantity will be required even in a city of modern size. Assuming a city having about 12 blocks to a mile, each square mile will have about 144 blocks; therefore, a city of approximately 10 sq. mi. would have about 1500 blocks. Assuming that the multiple circuits are so isolated that there is one circuit per block, then 1500 time switches would be required. Comparing this with the use of no time switches and 1500 relays, or a few time switches and 1500 relays, it can be readily seen that there will be a wide difference in the problem of maintenance.

Under certain conditions there seems to be an economy in favor of a multiple system irrespective of whether the control is by pilot wire, a combination of pilot-wire and time-switch control, or a straight time-switch control.

Apparently, the factor that throws the item of economy from the pilot-wire and relay scheme to the straight time-switch system, is the cost of the control wire. Mr. Kehoe has already developed this point in his discussion. However, Mr. Kehoe has emphasized purely the cost of the control wire. There is another and still larger factor in the pilot-wire scheme and that is the cost of the duct. If the distribution system is so laid out that the pilot wire can readily be pulled into a duct where an existing cable is installed, then the cost of the pilot wire is almost negligible due to the fact that the cost of the pilot wire installed is less than 25 per cent of the cost of the duct. Therefore, comparing the economy of the various types of control systems for a multiple street-lighting system, it is necessary to bear in mind the necessity of installing a pilot wire of reasonably low cost in a duct where existing cables are already installed. Otherwise the cost of the pilot wire and relay scheme will be considerably out of line with the cost of an individual time-switch system.

S. B. Hood (communicated after adjournment): This paper is of inestimable value to the industry in that it shows conclusively that street lighting in a large metropolitan area can be successfully and economically carried out without the complete duplication of distribution systems that are involved where series street-lighting circuits are employed.

The description of the New York multiple system is of particular interest to me in that I developed an almost identical system a few years ago for application in Minneapolis, where the bulk of the distribution system is overhead except in a limited congested commercial area. It was not until some months after the first Minneapolis installation was made that I learned of the details of the New York system, as developed by Mr. Dempsey. This duplication of development should serve as additional proof of the practicability of multiple remote-control street lighting.

In the Minneapolis system, where the control is scattered over an area far larger than the underground area in New York, the remote-control system as described in Mr. Dempsey's paper has been enlarged upon by the addition of cascading relays which serve to re-energize control-wire sections. In this manner, the area that can be controlled from any one control station becomes unlimited, thereby making the system even more flexible than any series system. The use of alternating current for the control

made necessary the design of a type of relay radically different from that used in the New York system where direct current is used. After considerable experimental development we now have a very simple and reliable a-c. relay that closes by gravity, thereby changing what would be an outage in most systems to a daytime "onage" in both the New York and Minneapolis developments.

With these two installations both operating with an efficiency and proven reliability far in excess of the best of series systems, requiring no duplication of existing investment other than a simple single-wire control circuit, and operating throughout at a voltage not in excess of 120 or 240, there no longer seems any justification for further installation of any form of series circuit which requires dangerously high voltages for its operation, with accompanying hazard to both operating staff and the general public.

It should also be considered that the multiple system operates at the same power factor as the general distribution circuits, usually close to 1.00. Where utility engineers are using every effort to improve the customer's power factor by offering inducement rates for better power factor it seems inconsistent for the same engineers to be purchasing and installing series street-lighting equipment that inherently operates at low power factors, 0.55 to 0.60 being fair averages.

It may be of particular interest to mention that a recent research of the patent situation regarding multiple street lighting showed that Thomas A. Edison developed and patented this remote-control multiple street-lighting system long before series circuits had been commercially developed, so that in adopting the remote-control multiple system we are doing nothing new, but just starting in on the second round of the circle.

W. T. Dempsey: I should like to speak of the points brought forth by Mr. Suydam. In street lighting we have two evils. We may burn lamps in the daytime and we may have them out at night. Personally, I should rather have them burning in the daytime than out at night. Street lighting, we must never forget, is a most important service rendered by a public utility. There is nothing of more importance as a police measure or for traffic reasons.

As to time clocks, they have their place. We have used them for 15 years in turning on and off Central Park, but where we can put a relay in the circuit, we feel there is greater reliability. We have a control circuit in our hands so to speak in the station and we are not bothered with adjusting a time clock to take care of the seasonal variations in time.

The number of lamps per relay, 5.3, mentioned by Mr. Suydam, is determined entirely by the size of conductor, allowing for a reasonable drop in voltage in effort to keep the conductor as small as possible. The system has been in very successful operation in New York since 1918 and has been growing steadily all the time. The best point in its favor is that other large cities are installing the same system.

The city of New York has applied to its police radio system a plan of telephone interconnection such as railroads of the country have used for some time in telephone train dispatching. All broadcasting on this system is on a wavelength of 3000 cycles which raises it beyond the reach of ordinary radio broadcasting so that there is small likelihood of interference. By the use of an attachment to a standard radio telephone transmitter the carrier current is modulated with an audio frequency tone in such a manner that the central operator can call any one of the several hundred receiving stations or reach them in groups or all at once. At each station is a visible and audible signal which attracts attention before each message goes out.

ILLUMINATION ITEMS

[By Committee on Production and Application of Light

HOME LIGHTING CONTEST IN FRANCE

A new spirit of decorative art is today permeating France. As in other fields, it found striking expression in the design and use of lighting fixtures at the International Exposition of Decorative Arts held last year in Paris. The ornamentation and the lighting of a room are inseparable. Recognizing this, artists and decorators often use light as the determining element in their decorative schemes and have produced wonderful and beautiful results. There are many householders, however, who cannot employ talented artists for this purpose but who, nevertheless, value such pleasing and effective lighting. To put it within their reach, the Societe pour le Perfectionnement de l'Eclairage and the Compagnie des Lampes are promoting a contest to develop lighting fixtures of a type suited to the average French home. Prizes amounting to 50,000 francs will be awarded.

The contest is divided into two parts. The first part is a competition for the best method of lighting three rooms of a French home—a living room, a dining room, and a bed room. The fixtures, or lighting systems, must be illustrated and described by full-scale plans and specifications. They must be of new design in the sense that copies and imitations of styles (ancient or modern) cannot qualify. The use of imitation candles and of unshaded lamps is specifically forbidden. The expected distribution of light from the fixture must be indicated and the contestants must endeavor to design their fixtures to diffuse the light in such a way that the brightness of walls and ceilings will bear a pleasing relation to the illumination of the room itself and so that there will be no objectionable glare. Moreover, the light-producing efficiency of the systems, as well as their decorative value, will be considered and the probable cost of the equipment will be taken into account.

This part of the contest does not require the design of any new fixtures and has been arranged to permit students and artists who have no facilities for constructing fixtures, or who could not go to the expense of having them made, to participate.

The second part of the contest is open to all those who have taken part in the first portion of the contest. Fixtures, such as recommended must be submitted for actual test in the rooms for which the lighting layouts were made. Each luminaire that has been designed for entry in this part of the contest will be subjected to tests so that its merits with respect to light distribution, efficiency, absence of glare and attractive appearance may be determined by the jury of awards.

A grand prize of 10,000 francs is offered to the winner in each part and with the exception of the grand prize winner in either contest it is possible that a competitor may win prizes in each.

This contest will undoubtedly stimulate further the already active interest of the French artists and decora-

tors in the use of artificial light as a decorative medium and help to impress the public with effects that can be obtained.

BRITISH HOME LIGHTING CONTEST BEGINS WITH A BURST OF ENTHUSIASM

One of the most elaborate campaigns ever put into operation for the development of the electrical industry has been launched in Great Britain under the auspices of the Electrical Development Association and the Electric Lamp Manufacturers Association. This activity is intended to promote the wiring of the homes of Great Britain and to spread the gospel of better home lighting. The campaign is receiving the enthusiastic and active support of all sections of the British electrical industry. The Technical Press is giving the movement its very hearty support and it would appear that the results could not be other than highly successful.

The immediate object of the activity is to arouse the interest of the public and the public press in the use of electricity in the home. To do this a national contest has been organized in which the competitors must indicate on sketches provided for the purpose their choice of lighting fixtures for various rooms in a home. This qualifies them to participate in the main competition which consists of a designation of what they believe will be the popular order of importance of twelve advantages to be derived from the use of electric lighting in the home.

The first prize in this competition is a house evaluated at £2000, completely wired and electrically equipped for lighting, heating, cooking and power. Other prizes are to be awarded for the 27 runners-up in the contest.

The electrical industry is being organized in district committees and electrical circles to carry on the work locally. Likewise an extensive publicity campaign is being conducted through the British newspapers. Electrical homes, of a demonstrational nature, will play an important part in educational work with the public during the contest. Leaflets, sales letters, window displays, and advertising novelties have been prepared for the use of the electrical trade in promoting the interest of the public in this activity.

In order to keep the electrical trade fully informed as to the progress of the work, a bulletin entitled "Home Lighting News" will be sent periodically to all those taking an active part in the work. This will report the progress which is being made throughout the country and will act as a general stimulant for sustained effort in all branches of the trade.

The campaign has been worked out with great care in every detail and with the support which has already been given to it, success is assured. It comes at a most opportune time because the British public has had its attention directed very forcefully to the electrical industry and the plans for its promotion and development through the recently proposed Electricity Supply Bill which has been such a live issue during the past few years. With the way now cleared for the rapid and extensive development of generation and distribution of electrical energy, this campaign dealing with the more effective and complete utilization of electricity on the part of the public, is all that is required to bring about one of the most remarkable developments of the electrical industry that any nation has ever seen.

A RECENT LIGHTING DEMONSTRATION IN HOLLAND

"Lighting" was chosen this year as the subject of the annual exhibit of the Academy at Rotterdam, Holland. With the assistance of several organizations, including the Dutch Illuminating Engineering Society, a demonstration of lighting effects and of good and bad lighting as it applied to a number of the more usual services was arranged. The exhibit also included displays relating to lamp manufacture, historical lamps, fixtures and portable lamps. Particular emphasis was placed on the proper use of light in the home, and in this connection the "camouflage" aspect of lighting was prominently featured.

Contrast of color, shade, silhouette, reflection and such phenomena can be used to disguise objects or to decieve the observer. Sometimes such effects are sought deliberately (as in camouflage work) but often they are produced unconsciously when they should be avoided, and some of the common faults of ordinary lighting in this respect were illustrated.

During the week that the exhibition was open, eight thousand visitors passed through it, and it aroused much interest not only on the part of the general public, but among architects, engineers, decorators and others who are responsible for lighting installations.

INCANDESCENT LAMP RATINGS IN FRANCE

The Syndicate of French Manufacturers of Incandescent Lamps announces that their metallic-filament vacuum incandescent lamps will hereafter be designated, as the gas-filled lamps have been for a long time, by their consumption in watts and not by their intensity in candle power.

The new lamps will replace the old in accordance with the following schedule:

Watts		C. P.
10	will replace	5 and 10
15	will replace	16
25	will replace	25
40	will replace	32
60	will replace	50
100	will replace	100

JOURNAL
OF THE
American Institute of Electrical Engineers

PUBLISHED MONTHLY BY THE A. I. E. E.
33 West 39th Street, New York
Under the Direction of the Publication Committee

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Subscription: $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $10.50 to Canada and $11.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th day of the month for the issue of the following month.

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The A. I. E. E. Winter Convention, New York, February 7-11

The 1927 Winter Convention of the Institute maintained its tradition of being the "Working Convention" of the year, as 35 technical papers were presented and discussed during the meeting, in addition to an address by President Chesney on "Standardization" which formed one of the important subjects for consideration. While the number in attendance is not always a criterion of the success of a convention, the attendance of over 1900 people is an indication of the wide interest in Institute affairs which the Winter Convention inspires. The variety of subjects presented, the high character of the papers, the large attendance at the various sessions, and the volume of discussion incurred all mark this convention as one of the most notable and important ones ever held by the Institute.

The Smoker

Entertainment light and attractive gave the proper atmosphere to the Smoker held in the Belvedere of the Hotel Astor on Monday evening, February 7. The 650 who attended were kept in good spirits by the very likable master of ceremonies Graham McNamee, the broadcast announcer of Station W E A F of the National Broadcasting Company. Mr. McNamee's vocal selections were also heartily enjoyed. The fencing matches between ladies and between men of the fencing class of the Brooklyn Edison Company proved really exciting. The large orchestra of this company also added joy to the occasion with music throughout the evening. Another feature was the Clover Leaf Trio who entertained with lively singing. A light supper closed this very enjoyable evening.

Inspection Trips

Over 500 members made the inspection trips which were arranged to eleven points of interest. Most of the trips were made on the morning of Thursday, February 10, though smaller parties visited some of the places on every day of the convention. The places visited were the new East River Station of the New York Edison Company, Hudson Avenue Generating Station of the Brooklyn Edison Company, the Staten Island Edison Company, the Electrical Testing Laboratories, the Bell Telephone Laboratories, Station W E A F of the National Broadcasting Company, a plant of the American Telephone and Telegraph Company where picture transmission over wires was demonstrated, the Paramount Theatre Building, the Holland Vehicular Tunnel and the Lighting Institute of the Edison Lamp Works.

The Dinner-Dance

The largest and one of the most enjoyable of the Institute's winter dinner-dances was attended by 720 members and guests on the evening of Wednesday, February 10, in the Ball Room of the Hotel Astor. This was an attractive gathering of charming ladies and their escorts who included many of the Institute's most prominent members. This, combined with the beauty of the ball room and its floral decorations, and the music from a perfect orchestra made everyone loath to leave until the last dance was played in the early morning hours.

The Technical Sessions

Monday Afternoon

The opening session was called to order by Mr. E. B. Meyer, chairman of the Meetings and Papers Committee who announced that prior to taking up the scheduled program President Chesney would address the meeting on the subject of *Electrical* Standardization after which the subject would be thrown open for general discussion. President Chesney's address which is printed elsewhere in this issue, advocated that all electrical standardization for the industry, wherever initiated, should ultimately come under the jurisdiction of the Institute. Mr. Chesney presented a tentative form of procedure whereby other interested groups in the electrical field should participate in the formulation of standards. Some brief discussions followed in which the tentative suggestions of President Chesney were endorsed.

The meeting was then turned over to Mr. H. M. Hobart, chairman of the committee on Electrical Machinery, and the following papers were presented in abstract:

Torque Angle Characteristics Under Transient Conditions, by R. E. Doherty and C. A. Nickle.

The M. M. F. Wave of Polyphase Windings, by Quentin Graham.

Transverse Reaction in Synchronous Machines, by J. F. H. Douglas.

Starting Performance of Synchronous Motors, by H. V. Putman.

The discussion on the Doherty and Nickle paper was by J. H. F. Douglas and R. D. Evans and chiefly concerned the statement that if a synchronous machine was operating beyond the angle corresponding to maximum steady-state power, the machine would be stable under sudden changes although steady-state characteristics at that point indicate instability. Mr. Nickle explained that this condition could actually be obtained by causing the excitation to vary in the right phase and in the right amount. Mr. Doherty stated that by applying the excitation at the right time, in the right phase it had been found possible in their experiments to nearly triple the power.

Mr. Graham's paper was discussed at some length by P. L. Alger and C. A. Nickle and referred chiefly to the simplification of some equations developed for expressing the magnitute of harmonics. The author agreed with the changes suggested.

Prof. Douglas' paper was discussed by H. V. Putman who thought that the method of measuring phase angle by the use of two wattmeters, while applicable to a two-phase machine, could not be applied to a three-phase machine. He also discussed the relative values of transverse and direct synchronous reactance and compared the different theories of Blondel, Berg, Arnold, Steinmetz, Karapetoff and others. Mr. Nickle doubted that the effect of saturation upon quadrature reactance was as great as the author concluded in his paper. Mr. Doherty stated that much of the difference of opinion in regard to reactance expressed in the discussion was due to the different conceptions of the definition of that word. Prof. Karapetoff stated that the principal value of the paper was the novel experimental method used to obtain partial data in addition to the usual load data. What is needed now is new experimental methods for measuring what is happening in this physical apparatus, without regard to previous theories.

Mr. Putman's paper was discussed by R. H. Park, who mentioned several assumptions in the paper which were not strictly true but which apparently did not interfere with obtaining results that check tests. P. L. Alger stated that by assuming the stator resistance to be zero the author failed to get the dip in the speed-torque curve that is developed by any motor with a single-phase rotor effect. Mr. Graham said he had worked out an equation, which included the stator resistance and found in applying it to several cases that the dip at half speed is very slight and therefore unimportant in practical applications. The author, while admitting various assumptions in his method of calculation justified them on the ground that the practical results agreed very closely with theoretical values.

Tuesday Morning

The session was called to order by Chairman Hobart, and the general subject of the meeting was Synchronous Converters and Losses. The first paper presented by Mr. Hambleton, was entitled *The Synchronous Converter—Theory and Calculations*, by T. T. Hambleton and L. V. Bewley.

In a written discussion, E. B. Shand stated that the formulas in the complex form given in the paper were not generally applicable in practical design calculations because accuracy of design calculations is limited by several factors not considered in the paper. Mr. Graham suggested several curves which might have been included but which were clearly outside of the intended scope of the paper. The closure was by Mr. Bewley.

Mr. Louis then presented a paper entitled *Constant-Current Regulating Transformer Characteristics*, by H. C. Louis and Arthur Albaugh, on which the discussion was opened by E. D. Treanor. Mr. Treanor said that the most important point brought out was that there was sufficient use of such transformers at quite low loads to justify more attention to light-load losses. The high temperature of coils and core due to increasing light-load losses was discussed. These transformers have not been specifically covered by Institute Standards and the only guide as to temperature at present must be experience with particular transformers. Mr. J. B. Gibbs suggested several schemes for overcoming the bad effects of the leakage flux. One was by changing shape of the core to a more or less elongated rectangle. Another scheme was to place copper plates at one or more places between the laminations. He thought the authors remarks about temperature were rather unduly alarming. Mr. Paxton asked about the losses at overload. Prof. Kouwenhoven inquired how the temperature in the floating winding was measured. A. F. Handi quoted some tests which he had made in 1925 and suggested a method of efficiency calculations, more or less empirical, which he found gave close results. Mr. Louis gave a brief closure.

The next paper was, *Additional Losses in Synchronous Machines*, by C. M. Laffoon and J. F. Calvert.

I. H. Summers asked the authors to explain the large difference in load losses shown for a 600 volt machine and a 2300 volt machine. W. F. Dawson criticized the use of the "stack" method of measuring losses and pointed out various inaccuracies which it involved. P. L. Alger pointed out that very small changes in structural details may make big differences in the losses. E. H. Freiburghouse inquired if the authors had used a baffle-type mixer for getting uniformity of temperature, and discussed the relative value of magnetic and non-magnetic end rings in relation to temperature and load losses. Mr. W. H. Colburn stressed the importance of stray losses to the users of the machines, and F. D. Newbury stated that it was important to establish the relation between the stray losses and the efficiency, for the benefit of the Institute's Standards Committee. J. F. Calvert in closing discussed the calorimeter method of measuring losses mentioned by Mr. Dawson, and Mr. Laffoon stated in answer to Mr. Summers' question that the losses are always higher in a one-conductor-per-slot type of winding, and drew some comparisons between the calorimeter and "stack" methods of testing.

The last paper of the session, *Reduction of Armature Copper Losses*, by I. H. Summers was abstracted by the author.

G. H. Rockwood, Jr. offered a method of plotting ratios given in Table II of the paper which simplifies the work of computation. P. L. Alger endorsed the type of winding suggested by Mr. Summers as it enables a machine-wound coil to be made without extra expense of special clips or special conductors for the slot portion. J. R. Dunbar thought the method of transposition of coils suggested was too complicated to be justified. F. D. Newbury discussed general considerations regarding transpositions, describing three methods which have been advocated. He also mentioned the paucity of literature on this important subject. Mr. Summers gave a brief closure after which the session adjourned.

Tuesday Afternoon

This session, also under the auspices of the Electrical Machinery Committee was called to order by Chairman Hobart. The first three papers of the session were upon the general subject of *Graphical Determinations of Magnetic Fields*, and the chairman called for the presentation of the first section, (a) *Theoretical Considerations*, by A. R. Stevenson, Jr. and R. H. Park. Both authors took part in presenting the paper. This was followed by the presentation of the next part, (b) *Comparisons of Calculations and Tests*, by E. E. Johnson and C. H. Green, abstracted by Mr. Johnson. The last paper of the series, (c) *Practical Applications to Salient-Pole Machines*, by R. W. Wieseman, was presented by the author. The three papers were discussed together.

C. H. Linder opened the discussion by showing a number of lantern slides of tests in which iron filings had been used as the means of determining flux distribution. C. M. Laffoon said that the mathematical method of analyzing flux distribution was undoubtedly the preferable and more scientific one and can be used for determining some features which would be difficult to determine otherwise. For practical applications, however, the iron filings method and the graphical method are very satisfactory. F. Calvert showed a number of lantern slides and argued the necessity of determining the flux paths in typical magnetic circuits to aid the calculation of more complex circuits. J. F. H. Douglas said that the templet method, while inadequate for some cases, was convenient to use as it involved less labor than the graphical method and much less than the mathematical method. He thought the possibilities of complex variables have not been fully appreciated. In closing, Mr. Stevenson called attention to the work of Lehmann who used purely graphical methods. Mr. Johnson called attention to the fact that the use of iron filings might lead to some misunderstanding in regard to the intensities of the fields on account of the tendency of the filings to gather in clusters where the flux density is high. Mr. Wieseman thought the use of templets would involve too much elaboration and expense to obtain all the coefficients necessary for design calculations.

The last paper of the session was *Reactances and Transformers which Carry Direct Current*, by C. R. Hanna, and was abstracted by the author.

Mr. D. C. Prince said these things have been made for many years by cut-and-try methods and he was glad to see Mr. Hanna's attack on empirical methods. There appears to be a maximum theoretical air gap of approximately 4 per cent of the total average magnetic path. The small air-gap reactor however, is made almost entirely of iron and there is hardly any copper in it. As the air-gaps are increased the ratios of copper to iron increase and it is necessary to strike a balance between copper and iron so as to get the most economical structure. J. F. H. Douglas stated that the paper showed an important theoretical advance in design but it was still a trial-and-error method. Mr. Hanna in closing drew comparisons between his own method and one suggested by Mr. Prince.

Wednesday Morning

Voltage Standards was the subject of the technical session on Wednesday morning, under the auspices of a special committee of which B. G. Jamieson was chairman. A symposium of seven papers was prepared, representing the views of the different groups in the electrical industry in regard to standardizing of voltages of a-c. supply system. These papers which were presented in abstract are entitled as follows:

Voltage Standardization of A-C. Systems from the Viewpoint of the Electrical Manufacturer, by H. R. Summerhayes and F. C. Hanker.

Voltage Standardization from a Consulting Engineer's Point of View, by R. E. Argersinger.

Standardization of Voltage Ratings for A-C. Power Systems and Equipment, by A. E. Silver and A. L. Harding.

Voltage Standards for Electrical Distribution, by H. B. Gear.

Voltage Standardization and Its Relation to the Interconnected Companies of the Southeast, by H. J. Scholz, W. W. Eberhardt and S. M. Jones.

The Suggested Transformer Voltage Standards and Their Relationship to Pacific Coast Practise, by Pacific Coast Electrical Association Subcommittee on Transformer Standardization, H. H. Minor, Chairman.

Standardization of Voltages, by A. Huber-Ruf.

Another paper on an allied subject but of a different character from the symposium was also presented at this session. It is entitled *Combined Light and Power Systems for A-C. Secondary Networks*, by Henry Richter.

Before opening the discussion of the symposium papers, Chairman Jamieson called attention to the conditions leading up to the present endeavor to bring about some unity of sentiment on the subject of standard voltages. He also explained that the question to be solved was not so much the adoption of an absolute "standard" in the strict sense of the word, but a movement towards unification and therefore the simplification of practise that would result.

The discussion on this subject continued during the balance of the morning, and also occupied the time of a special session on Thursday morning which was the time set aside for technical inspection trips. There appeared to be general acceptance of the utilization voltage as the standard of reference for any standard voltage system that might be adopted. Beyond this there seemed to be but little agreement among the speakers. The wide variety of opinions expressed and the unusual length of the discussion make it impossible to abstract adequately within reasonable length and an effort is being made to publish the complete discussion at an early date.

Wednesday Afternoon

Prof. V. Karapetoff acted as chairman at this session and called the meeting to order, saying that the four papers to be considered were somewhat similar in nature and would therefore be presented first and discussed as a group.

The first paper *A New 132,000-Volt Cable Joint* was presented by the author, D. M. Simonds. The next paper *Oil Breakdown at Large Spacing*, by D. F. Miner, was abstracted by the author. In the absence of F. D. Murnaghan, Prof. Karapetoff asked Mr. Buckley to occupy the chair while he presented the paper *Maxwell's Theory of the Layer Dielectric*, by F. D. Murnaghan, which he prefaced with an explanatory introduction. The last paper, by C. H. Willis, entitled *Space Charge and Current in Alternating Corona* was presented by the author.

D. W. Roper stated that a few of the cable joints described had been used in Chicago and it was found that a slight change which they thought might improve the joint was covered by a patent owned by another manufacturer, and the patent situation thus might eventually considerably hamper the development of the best possible joints. He said that the industry is forging ahead of the science in cable dielectrics and that we are not able to test a cable and predetermine its operating characteristics with accuracy. Predictions as to the life of a cable in service can frequently be made by visual inspection with fair accuracy but no test is available to check the visual examinations. T. F. Peterson questioned whether failure could be attributed to the lowering of the dielectric strength of long paths of oil. He doubted that the gradient in the oil overtakes the breakdown gradient. In his experience the breakdowns had been instead in the oil films. S. I. Osterreicher doubted the claim that any diameter of sleeve, providing it clears the paper insulation, may be put over the insulated joint. In his opinion the shape of the end bell or size of a cable sleeve, or in other words, the size and shape of two electrodes separated by a dielectric, may considerably increase the dielectric layer stress at certain critical points. O. R. Shurig drew attention to designs requiring large oil gaps and stated that data on small gaps when the voltages increase rapidly are also important, as the sudden formation of highly conducting ionized gases tends virtually to reduce the clearances between live and grounded parts. In regard to breakdown with oil containing water he found that the oil had cleared within three days after mixing with 3 per cent of water and had then practically regained its original dielectric strength. Joseph Slepian paid a tribute to Dr. Murnaghan's mathematical ability but doubted that such mathematical investigations threw any light whatever on the structure of the dielectric itself. He did not believe it sufficient to treat the dielectric as if the conductivity current could be applied according to Ohmes law. Donald Bratt discussed the physical conditions on which the mathematical treatment is based and then gave the derivation of a general solution for a stratified condenser based on the ideas of Heaviside. Prof. Kouwenhoven said that in cable work the question of absorption had become of prime importance and an investigation is now being carried on under the auspices of the National Research Committee and Engineering Foundation trying to prove or disprove Maxwell's theory of absorption. If two or more perfect dielectrics can be found they can be combined in layers to see if the results obtained check with the mathematics. Joseph Slepian speaking of Mr. Willis' paper thought a very important point was the proof that the beginning of corona is not the point where ionization begins. V. M. Montsinger called attention to Mr. Miner's statement that the strength of oil under certain conditions varies as the electrode spacing raised to the 0.7 power. If, however, the electrodes were large flat planes with rounded edges the strength varies almost directly with the spacing. This difference he thought was due to electrode shapes producing a distorted field which became more pronounced with increased spacing. R. J. Wieseman regretted that no single method of testing cable joints was in general use. One company uses one method and another company another method, so that the results cannot be conveniently compared. Referring to the effect of water in oil, he thought it possible that under high stress, with wide electrode spacings, there is attraction of moisture around the electrodes, causing an increase in the diameter of the conductor and thus a temporary increase in the stress until breakdown occurs.

F. W. Peek, Jr., spoke of the erratic behavior of oil under test and pointed out some of the reasons for it. These related to the action of occluded gases, moisture, conducting fibrous particles which may line up in certain ways in the electrostatic field. Alex. Nyman discussed high-frequency corona, pointing out that at high frequency corona begins at very much lower voltage than at 60 cycles. F. M. Clark said that in considering insulation data from the standpoint of the theorist we should be very careful in accepting test results based on ordinary commercial materials, important as they are to the engineer. It is very confusing to explain the fundamental nature of material, such as oil, when you are not working on the oil itself but on, say, suspended particles in the oil. W. A. Del Mar suggested a standard pressure inside a cable joint when being tested, to avoid the expansion due to generation of heat, and the creation of internal pressure in the joint. C. N. Rakestraw said that in Cleveland the stepped insulation cable joint had been abandoned in favor of one using a conical connector applied by undercutting the insulation, and which gave a breakdown voltage of 50,000 volts higher than that of stepped type. E. D. Eby commented on the stepped joint discribed by Mr. Simonds which he considered a very practical type of joint. Tests on this type of joint in his experience have shown in every case that it is stronger than the cable on which it was applied. He advocated a standard test so that all tests would be comparable, and the use of a thin mineral oil for filling the joints. After brief closures by the authors the meeting adjourned.

Thursday Afternoon

This session was held under the auspices of the Committee on Protective Devices and the subjects under discussion were circuit breakers and surge investigations. F. L. Hunt, chairman of the committee presided. Four papers were presented and discussed together. The papers were as follows: *Tests on Oil Circuit Breakers*, by P. Sporn and H. P. Sinclair; *Klydonograph Surge Investigations*, by J. H. Cox, P. H. McAuley and L. G. Huggins; *Transmission Line Voltage Surges*, by J. H. Cox; *The Measurement of Surge Voltages on Transmission Lines Due to Lightning*, by E. S. Lee and C. M. Faust.

J. D. Hilliard stated that his company had taken the stand that the operating engineers of the country should be fully informed and that it was realized that the only test that absolutely determines the full rated capacity of a breaker is the test made repeatedly at full rated capacity. The only thing proved by this however is the capacity under the particular conditions existing, and under different conditions entirely different results might be obtained. No general conclusions should be drawn from tests at part rated current or voltage. The G. E. Co. is building a testing generator with a sustained short-circuit capacity of 500,000 kv-a. and a testing laboratory equipped to test breakers of all voltages and currents.

K. B. McEachron discussed the papers on surge recorders and disputed the positive statements in regard to the prevalence of negatively charged clouds only, and the statement that lightning is unidirectional. The evidence points that way but is not sufficient to be conclusive. The time taken for a wave to reach its crest voltage determines the type of Klydonograph figure recorded. Lightning surges are about two microseconds in steepness. When current starts to flow electrostatic energy changes to electromagnetic, with a consequent drop in voltage, so that all the drop is not due to attenuation.

A. H. Shirmer did not agree with the conclusion that clouds which produce surges are always of negative polarity resulting in positive induced voltages or negative direct stroke voltages. A summary of his tests showed five storms produced positive surges, three storms produced negative surges and three other storms produced both positive and negative surges.

R. W. McNeill drew attention to the fact that in the circuit breaker tests the duration of arcing time was approximately alike for all the different designs, indicating that a two-break breaker will handle line voltage about as fast as a 10-break breaker. This is the first series of tests he had seen which seem to indicate that an ungrounded short circuit is no more severe than a grounded one. If this data can be verified the practise of using under voltage apparatus would be pretty well justified. F. W. Peek, Jr., felt grateful to Mr. Peters for giving us the Klydonograph as it afforded a means of checking conclusions that he reached some years ago regarding lightning. He gave a brief outline of some of his earlier work and stated he considered the check with the present papers was exceedingly good. He pointed out that it was very important to locate a station outside the usual paths of lightning strokes.

H. B. Vincent inquired whether any records of lightning voltage had been taken when the lines were not energized, also if any control devices had been used in connection with the insulators which might or might not affect the flashovers.

R. G. Hooke has been using the Klydonograph for about three years in connection with the company with which he is associated in New Jersey, and found that the percentages of different magnitudes checked very closely with the averages given in Table V of Messrs. Cox, McAuley and Huggins. He had only about half as many surges as the average due to switching at the Klydonograph station, and about twice the average due to switching at other points. Some of the surges recorded on this system were unusually high, two or three of which were described by Mr. Hooke.

G. A. Burnham agreed with Mr. Hilliard that when tests are to be made on apparatus for comparison, especially circuit breakers, the tests should be made in the same place, as nearly as possible at the same time, with the same recording instruments and should be run if possible under a master supervisor. He thought the 10-break circuit breaker more efficient than the 2-break method because of less gas evolution and consequently less pressure in the tanks.

Friday Morning

President Chesney opened the session on Friday morning the first event of which was the presentation of the John Scott Medal to one of the members of the Institute, Gustaf W. Elmen. This medal and a check for $1000 awarded to Mr. Elmen for his development of the metal permalloy, were presented by Louis Heilman, secretary of the Board of City Trusts, City of Philadelphia, which administers the medal. Mr. Elmen responded with a brief speech of acceptance.

H. P. Charlesworth then took the chair and called for presentation of the first paper of the session:

A New Electronic Rectifier, by L. O. Grondahl and P. H. Geiger.

Joseph Slepian said he had tested the elements of this rectifier and found the rectification was steady to a degree which was unbelievable after numerous studies he had made on other combinations of electrodes and separating films. He proved, he said, that there is an intervening layer of insulating film about 0.0001 cm. thick, between the copper and the oxide. This film gives the rectification.

George Crisson expressed interest in the telegraph system described in the paper as it seemed to give a duplex system by very simple means which would not depend on line balance.

Many questions were asked Mr. Gondahl and in replying he stated first that the maximum a-c. voltage which should be applied to an element is from 3 to 6 volts. There is no polarization and at such voltages the operation is limited only by the arrangement for carrying away the heat. When connected in series he said there is no tendency for the elements to divide the load unequally. He mentioned one combination he had used for ten months which gives one ampere at 1500 volts without any difficulty.

There is no such phenomenon as forming in the rectifier. It acts as a simple resistance. There is a slight increase in current with time in the high-resistance direction which is so small, however, as to be negligible in practical service.

If very high voltages are applied, 30 or 40 volts, the surface will puncture in one spot but there is no other evidence that the rectification takes place in spots. Lead is used as a contact because it is more impressionable than other common metals and makes a lower-resistance contact. With proper preparation the elements may be made uniform within 10 per cent of the output. The oxide is red oxide of copper, coprous oxide, and it is formed on the copper electrode under high temperature. Its thickness is immaterial as rectification occurs practically at the surface. About 0.002 to 0.003 in. is used. He concluded with the statement that the pressure applied does not affect the rectification but affects only the contact resistance on the outer surface of the oxide.

Harry Nyquist then presented the next paper, *Measurement of Telegraph Transmission*, by H. Nyquist, R. B. Shanck and S. I. Corey.

J. H. Bell in commenting on the paper stated that the methods described will be of great value in measuring the distortion in machine telegraph sections where the distortion must be kept down to 4 or 5 per cent which cannot be done accurately by the older methods. Answering a question by H. W. Drake, Mr. Nyquist stated that the particular system described does not lend itself to measurement of variation in lag, though some of the means might readily be developed to accomplish that purpose.

A paper entitled, *Telegraph Traffic Engineering*, by H. Mason and C. J. Walbran was then presented by Mr. Mason. J. H. Bell questioned the comparison between 55 to 60 words per minute for an automatic operator and 12 to 15 words for a Morse operator. Mr. Mason agreed that a Morse operator can work probably better at 20 words per minute but stated that the output is actually about 12 to 14. The output of the machine is probably fairly stated as 55. Mr. Bell mentioned that in England a new system of delivering telegrams has been started. A city is divided into routes on each of which a messenger starts at regular 5 minute intervals with all messages which have come in during the interval. Mr. Mason said that this system is not used by his company except for certain messages on which delayed delivery is allowed.

The last paper in the session was: *Developments in the Manufacture of Copper Wire*, by J. R. Shea and Samuel McMullan. This was presented by Mr. Shea and the meeting was closed with the showing of a film depicting wire drawing as described in the paper.

Friday Afternoon

In the Friday afternoon session at which A. E. Knowlton presided three papers were presented. The first of these was *A. C. Elevator Motor Drive*, by E. B. Thurston.

A discussion by P. A. Lindeman requested more information on several points such as details of stopping a fully loaded elevator traveling at full speed. He was of the opinion that the car would retard too abruptly just before stopping. He thought also that a compensator control would increase the efficiency and lower maintenance costs. J. Lebovici requested more design information on the motor and suggested also that the number of acceleration steps should be high. He mentioned an induction-type regulator now under development, which will given an infinite number of steps.

In answering these questions Mr. Thurston stated that the travel of the car when stopping after full speed could be regulated to practically any distance. He called attention to the fact that dynamic braking is used down to the low speed of the motor. The gear, he mentioned, for a high-speed machine is subject to less strain than for a low-speed machine. He said that an advantage of resistance-type control is that it gives a high power factor.

Two other papers on the subject of meters were then presented, these papers being: *A Stroboscopic Method of Testing Watthour Meters*, by H. P. Sparkes; *Compensation of Temperature Errors in A-C. Watthour Meters*, by D. T. Canfield.

H. J. Blakeslee called attention to an advantage of Mr. Sparkes' method of testing which is that the meter is tested while running which eliminates the errors of starting and stopping possible in other methods. G. A. Sawin elaborated on the advantage of eliminating the counting of disk revolutions and substituting a direct instantaneous indication of speed.

In answering several questions raised during the discussion Mr. Sparks explained that a magneto with a straight speed-voltage characteristic was used and that the straight portion only was used in the speed range of 4 per cent to 200 per cent of normal. He said it is necessary to keep the number of disk markings as high as 300 because with a smaller number of marks when testing at light loads the actual movement of the disk becomes visible.

He brought out that with this method meters may be tested without removing the covers, and covers will have to be removed only when calibration is necessary. He explained further that at 50 per cent power factor the method is as satisfactory as at 100 per cent. He stated that it is unsatisfactory to use the harmonic values for testing purposes as the accuracy is not good. He also suggested the use of a lens multiplier for testing at light loads. P. V. Kolff gave some information on tachometers and E. W. Beggs gave some details of the flickering lamp.

In commenting on Mr. Canfield's paper W. H. Pratt mentioned that many of the meters in use today have very much smaller errors than those used as a background in the paper. I. F. Kinnard agreed with this statement and said that the errors mentioned should be and could be to a large extent, eliminated in the design rather than by compensation.

A. R. Rutter said that the paper is of great value as a general analysis of the performance of watthour meters. C. T. Wallis mentioned that a bimetallic compensator is erratic and requires very careful adjustment.

In answering questions Prof. Canfield said that the compensated meters had been used in his laboratory for 2½ years. He said that if the bimetallic strips were properly prepared and aged they would not change.

The Kansas City Regional Meeting March 17 and 18

A program of unusual interest to members of the Southwestern District will be presented at the Regional Meeting to be held in Kansas City, Missouri, March 17 and 18, under the direction of District No. 7 of the American Institute of Electrical Engineers. The Kansas City Athletic Club at Eleventh and Baltimore Avenue will be Headquarters for the meeting.

Technical Papers

The subjects covered by the program will include Mercury Arc Rectifiers. Automatic Substations, Application of Electric Power to Flour Mills and the Petroleum Industry and Railway Signaling.

Student Conference

A meeting of Student Counselors and Student Chairmen is to be held March 16 on the afternoon preceding the Regional Meeting, for the purpose of discussing student activities in the District.

Banquet

An informal banquet for members and visiting ladies will be held in the banquet room of the Kansas City Athletic Club, fifth floor, Thursday evening. An interesting program is promised for that evening.

Register in Advance

All who will attend this meeting are urged to notify T. C. Ruhling, Chairman of Attendance Committee, 13330 Grand Ave., Kansas City, Missouri.

Hotel Accommodations

Members and their families may have the best of accommodations at the Kansas City Athletic Club and it is expected that the

majority of the visitors will take rooms there. Requests for rooms should be sent in advance to Mr. Marsh, Manager of the Club. The room rates are from $2.50 to $4.50. All rooms have baths. Meals may be obtained in the dining room on the sixth floor or in the grill room (for gentlemen only) on the fourth floor.

The ladies will be very comfortable at the Club as they will have there the accommodations of a high-class hotel.

Other Hotels

For members who do not care to register at the Club the following hotels are available within walking distance of the Club:

ROOM RATES PER DAY

Hotel	Bath	Shower	Without bath	Distance to K. C. A. C.
Aladdin	$3.00–4.00	2.00–2.50		2 Blocks
Baltimore	3.50		2.50	1 Block
Robt. E. Lee	2.00–2.50			3 Blocks
Muehlebach	3.50		2.50–3.00	1½ "
President	3.50–5.00	2.50–3.00		3½ "
Stats	3.00	2.50		1½ "

Each member should make his reservation in advance, direct with the manager of the hotel selected.

Inspection Trips

Trips of inspection have been planned to such plants as Northeast Generating Station and the a-c. and d-c. automatic substations of the Kansas City Power & Light Company, grain elevators and flour mills, stock yards, Sinclair Oil Company.

These inspection trips will permit only a brief stop at each place visited. The Entertainment Committee will be glad to arrange any special trips for those interested.

Lady Visitors

A number of members have notified the committee that they intend to bring their wives. The Entertainment Committee is making arrangements for special entertainment for the ladies during the technical sessions. This will include bridge, theatre parties and sight-seeing trips. The ladies are invited to the banquet Thursday evening, and to the dinner Friday evening at the Northeast Generating Station of the Kansas City Power & Light Company.

PROGRAM

Wednesday Afternoon, March 16

2:30 p. m. Student Council Conference on fifth Floor, Kansas City Athletic Club

Thursday Morning, March 17

Place—Roof Garden

9:00 a. m. Registration

10:00 a. m. Address of Welcome—A. E. Bettis, Vice-President, Seventh Geographical District, A. I. E. E.

10:30 a. m. Technical Session

Current Analysis in Circuits Containing a Resistance Modulator, L. S. Grandy, University of Missouri

Development of Railway Signaling, T. S. Stevens, Atchison, Topeka & Santa Fe System

Thursday Afternoon

2:00 p. m. Automatic Substation Session—Roof Garden

A 21,000 Kv-A Automatic Substation, D. W. Ellyson, Kansas City Power & Light Co.

Inspection, Maintenance & Test of Automatic Substation Equipment, Chester Lichtenberg, General Electric Co.

Carrier-Current Selector Supervisory Equipment, C. E. Stewart & C. F. Whitney, General Electric Co.

Thursday Evening

6:30 p. m. Banquet for members and ladies in banquet room—Informal

Friday Morning, March 18

9:00 a. m. Mercury-Arc Rectifiers Session—Roof Garden

Mercury-Arc Rectifiers, O. K. Marti and Harold Winograd, American Brown Boveri Co.

Steel-Tank Mercury-Arc Rectifiers, E. B. Shand, Westinghouse Electric & Mfg. Co.

Application of Mercury-Arc Power Rectifiers, C. A. Butcher, Westinghouse Electric & Mfg. Co.

12:30 p. m. Luncheon with the Kansas City Electric Club

Friday Afternoon

2:00 p. m. Oil and Milling Industries Session—Roof Garden

Application of Electric Power to the Petroleum Industry, B. K. Howard, Texas Power & Light Co.

Electricity for Oil-Well Drilling, L. J. Murphy, Westinghouse Electric & Mfg. Co.

Electric Welding of Pipes, J. F. Lincoln, Lincoln Electric Co.

Electricity in the Milling Industries, G. C. Meyer, Kansas City Power & Light Co.

Friday Evening

6:30 p. m. Dinner at Northeast Station of the Kansas City Power & Light Co.

COMMITTEES IN CHARGE OF KANSAS CITY REGIONAL MEETING

General Committee: A. E. Bettis, Vice-President in Seventh District; Henry Nixon, Secretary of Seventh District; R. L. Baldwin, G. O. Brown, S. M. DeCamp, E. R. Page and L. N. Van Hook.

Entertainment Committee: William M. Hand, Chairman; John W. Carrothers, Henry H. Kuhn, Arthur L. Mullergren, Mrs. Robert L. Conlin, Mrs. A. E. Bettis, Mrs. Henry Nixon and Mrs. R. L. Baldwin.

Reception Committee: M. M. Boggess, Chairman; R. L. Baldwin, S. M. DeCamp, George S. Gillespie, Wm. Hand, A. L. Mullergren, A. L. Maillard, Henry Nixon and J. F. Porter.

Transportation Committee: Thomas B. Bash, Chairman; Braxton Blasser, T. G. Hieronymus and John E. Launder.

Hotel and Registration Committee: George Fiske, Chairman; W. O. Edwards and W. J. Squire.

Attendance and Publicity Committee: T. C. Ruhling, Chairman; J. E. Busher, Bruce E. Dolch, B. J. George and Herman C. Henrici.

Speakers and Technical Meeting Committee: Glen S. Morris, Chairman; G. H. Ahlborn, M. M. Boggess, D. D. Clarke, Albert L. Maillard, E. R. Page, C. E. Reid, Geo. C. Shaad and M. P. Weinbach.

Finance Committee: J. F. Porter, Chairman; H. W. Eales, W. M. Hand and Henry Nixon.

Bethlehem Regional Meeting April 21-23

The program for the regional meeting to be held at Bethlehem, Pa., April 21-23, under the direction of Geographical District No. 2 of the Institute is now in practically final form. Quite a variety of technical papers on pertinent topics will be presented and other features, such as a banquet and inspection trips, will add to the attractions of the meeting.

The technical subjects to be presented are as follows: Mercury arc rectifiers, intercommunication systems, effects of lightning on transmission lines, circuit breakers, losses in distribution systems, voltage standardization, induction motors and applications of electricity in steel mills, cement mills and coal mines.

A feature of the banquet which will be held on the evening of April 21 will be the address of M. H. Aylesworth, president of the National Broadcasting Company.

A number of trips of inspection will be made to points of interest in the Lehigh Valley district.

In conjunction with the meeting there will be held on April 23 a conference of Branch Counselors and student chairmen of the Branches of the District.

The general committee in charge of the meeting is as follows: W. E. Lloyd, Jr., Chairman; R. T. Greer, W. H. Lesser, A. G. Pierce, C. S. Ripley, D. M. Simons and M. R. Woodward.

The local committee chairmen directly in charge of various activities are as follows: Finance, D. M. Petty; Program, J. L. Beaver; Transportation, L. C. Josephs; Trips, H. G. Harvey; Registration, James Huebner; Banquet, M. R. Woodward; Publicity, L. R. Woodhull; and Attendance, Geo. M. Keenan.

PROPOSED PAPERS FOR BETHLEHEM REGIONAL MEETING

Mercury-Arc Rectifiers, O. K. Marti and Harold Winograd, American Brown Boveri Co.

Intercommunication in Industrial Plants, L. A. Cutshall, Automatic Electric Corp.

Lightning and Its Effects on Transmission Lines, J. H. Cox, Westinghouse Elec. & Mfg. Co.

Oil Circuit-Breaker Developments, R. M. Spurck, General Electric Co.

Reducing Losses in Electric Systems, J. B. Moorhouse, Central Illinois Public Service Co.

Committee Report on Voltage Standardization, B. G. Jamieson, Commonwealth Edison Co.

Recent Developments in Large Induction Motors, D. F. Alexander, Westinghouse Elec. & Mfg. Co.

Recent Improvements in Electric Drives for Rolling Mills, L. A. Umansky, General Electric Co.

Application of Electricity to the Cement Mill, W. E. North, Coplay Cement Mfg. Co.

Application of Electricity in the Coal Mine, E. B. Wagner, Lehigh Valley Coal Co.

Regional Meeting at Pittsfield May 25-27

The fourth regional meeting of the Northeastern District of the Institute will be held at Pittsfield, Mass., May 25-27. A general arrangement of the program has already been decided upon and sessions have been proposed on the subjects of accuracy in high-frequency measurements, mechanical forces in electrical circuits and tap-changing transformers. Other subjects also will be included and special consideration will be given to authors who present their initial papers at this time. It is planned also to have a student convention in connection with this meeting and a session will be devoted to student papers.

The committee which is planning this meeting is as follows: H. M. Hobart, Vice-President in District No. 1; A. C. Stevens, Secretary of District No. 1; W. H. Colburn, E. D. Dickinson, E. F. Gehrkens, C. H. Kline and A. E. Soderholm.

Future Section Meetings

Akron

Starting of Large A-C. Motors, by P. C. Jones, The Goodyear Tire and Rubber Co. March 18.

Joint meeting of the Akron and Cleveland Sections at the Ohio Insulator Works, Barberton, Ohio. Some new researches and manufacturer developments, including carrier-current inspection. April 21.

Cleveland

Moving Traffic with Light, by C. E. Egeler, Nela Park. Other phases of the subject will be given by representatives of the City, the Railway Co., and the Auto Club. Joint meeting with Illuminating Engineering Society. March 24.

Columbus

Banquet Meeting. March 25.

Talks by local members. Buffet lunch and smoker. April 22.

Lynn

Banquet. Boston. March 26.

Pittsburgh

Power-System Stability—A Mechanical Analog, by Charles Fortescue, Westinghouse Elec. & Mfg. Co. Chamber of Commerce Bldg., 8:00 P. M., March 8.

Pittsfield

Electron Theory. March 8.

St. Louis

Railway Electrification, by Dr. W. H. McClelland, McClelland & Junkersfeld, Inc., (Past President, A. I. E. E.). March 16.

Annual Meeting. Election of officers. April 20.

Sharon

Steel-Mill Electrification. April 5.

Vancouver

Hydroelectric Developments of the East Kootenay Power Co., by M. L. Wade. April 5.

Summer Convention to be Held in Detroit, June 20-24

The Summer Convention of the Institute will be held this year in Detroit, Mich., on June 20 to 24. A technical program of widely varied topics is being planned and the local convention committee in Detroit has promised recreation and entertainment.

One of the most interesting suggestions in connection with the convention is that of a Great Lakes steamer trip. At the close of the convention it is proposed to take a four-day trip on one of the large lake boats, making a circuit including Mackinac Island and Georgian Bay. A special committee is studying the matter and if such a trip is found to be feasible, further announcements will be made.

The committee for this convention as appointed by President C. C. Chesney is as follows: Alex Dow, Chairman; G. B. McCabe, Vice-Chairman; Harold Cole, J. H. Foote, B. G. Jamieson, C. Kittredge, G. E. Lewis, A. H. Lovell, A. C. Marshall, A. A. Meyer, E. B. Meyer and Harold B. Smith.

Dr. Pupin to Address New York Engineers on the Romance of Research

On the evening of Wednesday, March 23, 1927, the members of the New York Electrical Society and the New York Section of the A. I. E. E. will have the great privilege of listening to an address by Dr. M. I. Pupin of Columbia University on the romance and necessity of scientific research. Dr. Pupin, who is a past-president of the New York Electrical Society, the American Institute of Electrical Engineers and the American Association for the Advancement of Science, will speak under the auspices of the National Research Council. He will recount, in his own inimitable way, some of the adventure stories of research. As the Doctor states, "research is no dry-as-dust subject but one of the most interesting adventures any man could undertake." The meeting will be held in the Engineering Auditorium, 29 West 39th St., New York, at 8.15 p. m., Wednesday, March 23, 1927. It is good to hear an enthusiast and Dr. Pupin is one of the world's best.

A. I. E E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Thursday, February 10, 1927.

There were present: President C. C. Chesney, Pittsfield, Mass; Past President Farley Osgood, New York; Vice-Presidents A. G. Pierce, Cleveland; W. P. Dobson, Toronto; H. M. Hobart, Schenectady; B. G. Jamieson, Chicago; G. K. Knight, Brooklyn, N. Y.; A. E. Bettis, Kansas City—Managers H. P. Charlesworth, H. A. Kidder, New York; J. M. Bryant, Austin, Tex.; E. B. Merriam, Schenectady; M. M. Fowler, Chicago; E. C. Stone, F. J. Chesterman, Pittsburgh; H. C. Don Carlos, Toronto—National Secretary F. L. Hutchinson, New York. Present by invitation: F. B. Jewett, A. I. E. E. representative on Electrical Advisory Committee of the A. E. S. C.; William McClellan, Chairman, Subcommittee of the U. S. National Committee of the I. E. C. on Revision of Scope of the U. S. N. C.; C. E. Skinner, Chairman, American Engineering Standards Committee; C. H. Sharp, President, U. S. National Committee of the I. E. C.; J. F. Meyer, Chairman, A. I. E. E. Standards Committee; L. T. Robinson, A. I. E. E. representative on A. E. S. C.

The minutes of the Directors' meeting held December 10, 1926, were approved as previously circulated.

The Board ratified the action of the Executive Committee, under date of January 21, 1927, in approving applications for Student enrolment, admission to membership, and transfer from one grade of membership to another.

Reports were presented of meetings of the Board of Examiners held January 14 and 26, 1927, and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners the following applications were taken upon pending applications: 73 Students were ordered enrolled; 284 applicants were admitted to the grade of Associate; 9 applicants were admitted to the grade of Member; 1 applicant was transferred to the grade of Fellow; 24 applicants were transferred to the grade of Member.

The Finance Committee reported approval for payment, of monthly bills amounting to $37,093.62, and the purchase of bonds approximating $15,000 in amount for the Reserve Capital Fund, as authorized by the Board at a previous meeting, the specific investments selected having been approved by the Executive Committee. The Board ratified the Executive Committee's approval of the investments selected.

In accordance with Section 22 of the constitution, the Board voted that Messrs. H. W. Weller and Frank E. Smith be added to the list of "Members for Life."

Upon recommendation of the Committee on Student Branches, authorization was given for the establishment of a Student Branch of the Institute at Duke University, Durham, N. C.

The Special Committee on Technical Activities reported on a suggestion which had been referred to the committee for recommendation, that a technical committee be formed to deal with the subject of arc welding. The committee recommended the creation of a new technical committee to be known as the Committee on Electric Welding, with duties "concerned with all matters relating to electric welding in the same manner as said duties are defined for the other technical committees," it being the opinion of the committee that "electric welding has become sufficiently a distinct branch of work of our profession to warrant the special consideration for it that the designation of this committee will give." The Board voted to authorize the creation of a technical Committee on Electric Welding.

Upon request of Dr. George F. Kunz, President of the Association for the Establishment and Maintenance for the People in the City of New York of Museums of the Peaceful Arts, for the endorsement by the Institute of the plan for the proposed Museums and for the Institute's cooperation by the appointment of a small advisory committee, the Board adopted the following resolution:

Resolved: That the Board of Directors of the American Institute of Electrical Engineers notes with pleasure and endorses the movement for the establishment of Museums of the Peaceful Arts in the City of New York, and accepts the invitation to appoint an advisory committee to assist the Museum authorities in the development of the necessary plans, particularly with reference to a suitable exhibit of the electrical industry in these Museums.

President Chesney presented an address, on electrical standardization, which he had delivered at the opening session of the Winter Convention (and which is printed elsewhere in this issue). A general discussion on the subject of standards followed, and the following motion was adopted:

Voted to approve in principle the standards policy as set forth in President Chesney's address at the Winter Convention, February 7, and as presented in full to the members of the Board present at this meeting, and to empower the president to take any steps that he thinks desirable with a view to putting these principles into effect.

Other matters of importance were discussed, reference to which may be found in this and future issues of the Journal.

Rating Sections of Induction Motor Standards Revised

By action of the Board of Directors of the Institute at their meeting of February 10, 1927 the Standards for Induction Motors and Induction Machines in General, No. 9, were revised. The revision adopted covers the sections of the Standard dealing with rating and is the result of the continued efforts of the A. E. S. C. Sectional Committee on Rating of Electrical Machinery to obtain a decision satisfactory to all. Such unanimous approval has finally been obtained by the Rating Committee under Dr. D. C. Jackson's chairmanship and the decision reached will now be applied to the revision of rating sections of Pamphlets 5 and 7 on "Direct-Current Generators and Motors" and "Alternating-Current Generators, etc.," respectively.

Revisions of pamphlet No. 9 follow, and will be inserted in that Standard at the points indicated by the numbering system:

"9-60½ Induction power motors, not specifically designed and listed for specific power application (where the load requirements and duty cycle are definitely known), are termed general purpose motors.

"A general purpose induction motor is any induction motor larger than the fractional horse-power motor, and not over 200 horse power, and 450 or more revolutions per minute, having a continuous time rating, and designed, listed, or offered in standard ratings for use without restriction to a particular application."

"9-105½ Rating of open-type general purpose induction motors. Open-type general purpose induction motors shall have only one rating (see paragraph 9-60½)."

"9-500 Allowable Variation from Rated Voltage.—All motors shall operate sucessfully at rated load and frequency with voltage not more than 10 per cent above or below rated voltage but not necessarily in accordance with the standards established for operation at normal rating."

"9-501 Allowable Variation from Rated Frequency.—All motors shall operate successfully at rated load and voltage with frequencies not more than 5 per cent above or below the rated frequency but not necessarily in accordance with the standards established for operation at normal rating."

"9-502 Allowable Combined Variation of Voltage and Frequency.—All motors shall operate successfully at rated load with combined variation in voltage and frequency not more than 10 per cent above or below the rating, provided the limits of variations given in Pars. 9-500 and 9-501 are not exceeded, but not necessarily in accordance with the standards established for operation at normal rating."

Insert as a heading to Table I of Paragraph 9-150 of Pamphlet No. 9—

"Table I—Limiting Temperature Rise for all Induction Machines Except General Purpose Open-Type Motors."

Insert the following new paragraph:

"9-150½—Limiting Temperature Rise of Open-Type General Purpose Motors. (See paragraph 9-60½). The temperature rise on which the rating is based shall be for the coil windings and for the cores and mechanical parts in contact with or adjacent to the insulation, 40 degrees centigrade. This low limiting temperature rise is provided to allow a greater factor of safety where the service conditions are unknown.

Such a motor operated at its rated voltage and frequency will carry continuously 1.15 times its rated load with possible slight differences in efficiency and power factor from those at rated load. This factor of 1.15 shall be known as the service factor. It is recommended that the service factor be marked on the name-plate in addition to the rating. (See paragraph 9-105½)."

Add to paragraph 9-150 of Pamphlet No. 9, Table II as follows:

TABLE II
LIMITING TEMPERATURE RISES FOR GENERAL PURPOSE OPEN-TYPE INDUCTION MOTORS

Item	Machine part	Class A Insulation (See par. 9-152)
1	Coil windings............................	40 deg. cent.
2	Cores and mechanical parts in contact with or adjacent to insulation....................	40 deg. cent.
3	Collector rings and commutators...........	35 deg. cent.
	Miscellaneous parts (such as brush holders, brushes, pole tips, etc.) other than those whose temperatures affect the temperature of the insulating material may attain such temperatures as will not be injurious......	
5	Squirrel-cage windings may reach such temperatures as will not occasion mechanical injury to the machine.....................	

Holland Vehicular Tunnel the Subject of New York Engineers' Meeting

A joint meeting of the New York Sections of the A. I. E. E., the A. S. M. E., the A. S. C. E. and the A. I. M. E. will be held in the Engineering Auditorium, 29 West 39th Street, at 8 p. m. sharp, on the evening of March 16, to listen to a talk by Ole Singstad, Chief Engineer, New York State Bridge and Tunnel Commission, who will have as his subject, *The Planning and Construction of the Holland Tunnel.*

Mr. Singstad will be supported in his talk by specialists who have been instrumental in handling certain features of the tunnel, notably the ventilating and electrical equipment. These features will be discussed by A. C. Davis, American Society of Mechanical Engineers and J. N. Dodd, Electrical Engineer, both on the tunnel engineering staff.

Colonel John R. Slattery, Deputy Chief Engineer, Board of Transportation, New York City, will preside, Mr. Slattery being Vice President of the New York Section of the American Society of Civil Engineers.

All engineers interested in this great public development are welcome to attend.

Hearings Continue on Metric System

Several hearings have recently been held before the Senate Committee on Commerce on the bills proposing to make the use of the metric system compulsory in this country, and to establish a commission to gradually bring this system into effect. It was proposed to complete these hearings during the month of June, but because of pressure of other work before the committee, it now appears doubtful whether the hearings will be completed at all during the present session of Congress. It will be recalled that hearings were held before the House Committee on Weights and Measures, during the last session of the present Congress, but that the Committee failed to report the measures on which they had taken testimony.

New Compilation of Laws on Weights and Measures

A new compilation of weights and measures, laws of the states, territories, insular possessions, and of the Federal Government of the United States, is being made by the Bureau of Standards.

This compilation includes the Weights and Measures Laws passed by Congress and the regulations issued thereunder by the several bureaus which have been concerned. It shows the existing law on the subject through the 1925 sessions of the legislatures.

It is stated by the Bureau that this publication should be very useful to manufacturers and shippers in interstate commerce, manufacturers of weights and measures apparatus, weights and measures officials and others concerned with law enforcement, of weighing inspection bureaus, and other officials concerned with weights and measures.

It is estimated that the finished work will contain about 1000 pages, and will be sold by the Government Printing Office at actual cost.

Columbia University Offers Scholarship in Electrical Engineering

The governing bodies of Columbia University have placed at the disposal of the American Institute of Electrical Engineers each year a scholarship in Electrical Engineering in the Schools of Mines, Engineering and Chemistry of Columbia University. The scholarship pays $350 toward the annual tuition fees which vary from $340 to $360, according to the details of the course selected. Reappointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of a good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements, in regard to which full information will be sent without charge upon application to the Secretary of the University or to the National Secretary of the Institute.

In a letter addressed to the National Secretary of the Institute, an applicant for this scholarship should set forth his qualifications (age, place of birth, education, reference to any other activities, such as athletics or working way through college, references and photograph). A committee composed of Messrs. W. I. Slichter, Francis Blossom and H. C. Carpenter will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for filing of applications for 1927-28 will be June 1, 1927.

The course at the Columbia Schools of Mines, Engineering and Chemistry, is three years in length and is on a graduate basis. A candidate for admission must have had something of a general education, including considerable work in mathematics, physics and chemistry. Three years of preparatory work in a good college or scientific school should be sufficient, if special attention has been given to the three preparatory subjects mentioned. A college graduate, with a Bachelor of Science degree in engineering can generally qualify to advantage. The candidate is admitted on the basis of his previous collegiate record, and without undergoing special examinations.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that enrolled students and others qualified will show a keen interest in this scholarship.

Elihu Thomson Honored

Professor Elihu Thomson, director of the Thomson research laboratory of the General Electric Company at Lynn, Mass., and past-president of the Institute, has been notified that he has received the Faraday medal of the Council of the Institution of Electrical Engineers of England for 1927. The award is made for "notable scientific or industrial achievements in electrical engineering, or for conspicuous services rendered to the advancement of electrical science."

International Electrotechnical Commission Sixth Plenary Meeting

It has been found necessary to slightly advance the date of the opening meeting of the International Electrotechnical Commission to be held in Italy; it will take place at Bellagio, Monday, September 5, 1927.

At the conclusion of the meetings of the Advisory Committees, the Italian Electrotechnical Committee, with the consent of the Italian Government, has arranged a short tour to include Milan, Venice, Florence and Rome. This will give the delegates a unique opportunity to visit these points of interest both for their artistic values as well as their historical background. Visits to important hydroelectric plants have also been arranged and the Italian Government has courteously agreed to place a special train at the disposal of the delegates. All traveling will be done by day service. At the end of the tour, the Plenary Meeting will be held at Rome, on September 21. Details of the program will be announced later.

Columbia Appoints Committee on Engineering Training and Research

President Nicholas Murray Butler of Columbia University, it is announced, has appointed a committee of alumni of the Engineering Schools to study from the practising engineer's point of view some of the present problems relative to engineering training and research as regards professional duty and opportunity in this connection. The committee, which will report to President Butler, is headed by Milton L. Cornell of the class of 1905. The other members are Daniel E. Moran, C. E., 1884, consulting engineer; Arthur S. Dwight, M. E., 1885, consulting engineer, Gano Dunn, E. E., 1891, president of the J. C. White Engineering Corporation; Francis Blossom, C. E., 1891, partner of Sanderson and Porter; Harris K. Masters, M. E., 1894, formerly president of the Engineering Alumni Association; Henry C. Carpenter, E. E., 1899, general manager, New York Telephone Company; Richard E. Dougherty, C. E., 1901, engineering assistant to the president of the New York Central Lines; Darwin S. Hudson, C. E., 1901, construction engineer, Consolidated Gas Company; David M. Myers, M. E., 1901, consulting mechanical engineer; Elihu C. Church, C. E., 1904, consulting engineer; Milton L. Cornell, C. E., 1905, president of the Cornell Iron Works, Inc.; John J. Ryan, E. E., 1909, engineer, New York Edison Company; Roy U. Wood, Met. E., 1914, assistant treasurer, Research Corporation; Frederick W. Jewett, Chem. E., 1918, consulting engineer; Stephen P. Burke, Chem. E., 1920, director of Research Laboratory.

The committee will conduct the study in consultation with the Faculty of Applied Science, and such Trustees of the University as have been graduated in engineering. This will include:

General William Barclay Parsons, C. E., 1882, member of the engineering firm of Parsons, Klapp, Brinckerhoff and Douglas; Walter H. Aldridge, E. M., 1887, president of the Texas Gulf Sulphur Company; Frederick Coykendall, C. E., 1897, president of the Cornell Steamship Company; H. Hobart Porter, E. M., 1886, president of the Brooklyn City Railroad Company, and of the firm of Sanderson and Porter.

ENGINEERING FOUNDATION

DEED OF GIFT

Edward Dean Adams, in making his generous contribution of $100,000 to the Engineering Foundation and Engineering Societies Library fund, detailed notice of which appeared in the May 1926 issue of the Journal, utilized the following "Deed of Gift," which has been made the accepted form for other future similar bequests.

DEED OF GIFT

DEED OF GIFT, dated January 20th, in the year of our Lord, One thousand nine hundred and twenty-seven, made by Edward Dean Adams, of "Rohallion," Borough of Rumson, Monmouth County, New Jersey, hereinafter referred to as the Donor, to United Engineering Society, a corporation organized and existing under the laws of the State of New York, hereinafter referred to as the Donee.

WHEREAS, United Engineering Society was incorporated on May 11, 1904, under Chapter 703 of the Laws of the State of New York, and has established two Instrumentalities or Departments, one the "Engineering Foundation Board" with power and authority to utilize the income from a fund of United Engineering Society, known as the "Engineering Foundation," and the other the "Library Board," charged with the custody and administration of the library known as the "Engineering Societies Library," in which are included the libraries belonging to each of the Founder Societies, namely, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers and American Institute of Electrical Engineers, and those books the title to which is vested in United Engineering Society, in accordance with the "Library Agreement," dated August 10, 1916: and

WHEREAS, it is the desire of the Donor to establish a fund to be known as the Edward Dean Adams Fund, for the benefit of the Donee through its two Instrumentalities or Departments namely, The Engineering Foundation Board and the Library Board or other substituted instrumentalities hereinafter provided for;

NOW, THEREFORE, in consideration of the premises, the Donor hereby gives to United Engineering Society, the Donee, the sum of One hundred thousand dollars ($100,000) to be received, held and administered by the Donee, and the income thereof to be divided into two equal parts, one part to be paid over to the Engineering Foundation Board, and the other part to the Library Board, "or such other instrumentalities as may in the discretion of the United Engineering Society be designated to fulfill the functions now carried out by said Boards," at such times as the Donee in its sole discretion shall consider advisable, for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind.

The Donee is hereby authorized and empowered from time to time to invest and reinvest said fund in such securities as it may deem suitable, and shall not be restricted to securities of the character authorized by the laws of the State of New York for trust investments.

United Engineering Society, in consideration of the gift above declared, hereby accepts said gift and agrees to carry out the purposes thereof through its Engineering Foundation Board and its Library Board, or other competent instrumentalities.

This instrument is one of two originals, both of like tenor and effect.

IN WITNESS WHEREOF, the undersigned, Edward Dean Adams, has hereunto set his hand and seal, and the corporation United Engineering Society has caused these presents to be executed in its name and behalf by its officers thereunto duly authorized and its corporate seal to be hereunto affixed this twentieth day of January in the year of our Lord, One thousand nine hundred and twenty-seven.

EDWARD DEAN ADAMS

Witness:
KEMPTON ADAMS

UNITED ENGINEERING SOCIETY
By
W. L. Saunders
President

Corporate Seal
Attest:
Alfred D. Flinn
Secretary

OFFICERS ELECTED FOR 1927

At the annual meeting held in the Engineering Institute Building, February 17, 1927, Lewis Buckley Stillwell, past-president of the American Institute of Electrical Engineers and the American Institute of Consulting Engineers, was reelected chairman of the Engineering Foundation for the third time.

Mr. Stillwell is also a member of the American Society of Civil

Engineers the Institution of Electrical Engineers of Great Britain, the American Engineering Council, the National Academy of Sciences, the Royal Society of Arts in Great Britain, the American Philosophical Society, and the Franklin Institute.

Arthur D. Little, founder and president of the Arthur D. Little Laboratories of Cambridge, Mass., and inventor of many chemical processes, was elected a vice-chairman: George A. Orrok, a member of the American Society of Mechanical Engineers, the American Institute of Mining and Metallurgical Engineers, and the American Society of Civil Engineers, was re-elected vice-chairman.

J. Vipond Davies, representing the American Institute of Mining and Metallurgical Engineers and Dean Arthur M. Greene, Jr., of the Princeton School of Engineering were named again as members of the Executive Committee. Other officers elected were: Director and Secretary, Alfred D. Flinn; treasurer, Jacob S. Langthorn; assistant treasurer, Harry A. Lardner.

New members of the Foundation Board are William H. Burr, consulting engineer, formerly professor of civil engineering at Columbia University to represent the American Society of Civil Engineers, and George L. Knight of the Brooklyn Edison Company, representing the United Engineering Society as trustee of the American Institute of Electrical Engineers, and Alva C. Dinkey, former president of the Carnegie Steel Company, member at large. New research projects proposed to the Foundation, which cannot be immediately undertaken because of lack of funds, were discussed. The gathering marked the close of the eleventh year of the Foundation.

Ohio State Offers Research Fellowship

The College of Engineering of the Ohio State University at Columbus, Ohio, announces a research fellowship. The value of this is $750.00 per year, and it is open during the coming college year, to graduates in mechanical, civil, and electrical engineering. The holder of this fellowship devotes his entire time to graduate work and may obtain the Masters Degree at the end of one year.

Further information may be obtained from the Secretary of the College of Engineering.

United Engineering Society

TREASURER'S REPORT FOR YEAR 1926

The following statement has been made by the Treasurer of the United Engineering Society for the year of 1926:

SUMMARY

Operation of Building

Credit Balance January 1, 1926		$ 8,641.03
Miscellaneous Adjustments		1.50
Building Revenue 1926	$130,211.60	
Building Expenditures 1926	104,787.66	25,423.94
		34,066.47
Annual Payment to Dep. & Renewal Fund	12,000.00	
Additional Payment to Dep. & Renewal Fund	3,531.25	
Added to Real Estate	6,840.98	22,372.23
Credit Balance December 31, 1926		11,694.24

Operation of Library

Maintenance Revenue	41,844.39	
Maintenance Expenditures	42,404.53	
Deficit December 31, 1926		−560.14
Service Bureau Revenue	19,145.95	
Service Bureau Expenditures and Adjustments	18,068.86	
Operating Balance and Adjustments	1,077.09	
Credit Balance December 31, 1925	856.25	1,933.34
Credit Balance December 31, 1926		1,373.20

Funds and Property

Funds Held by U. E. S. Dec. 31, 1926 (Book value)	
Depreciation and Renewal	215,887.39
Engineering Foundation	489,843.46
Henry R. Towne Engineering	49,987.58
Library Endowment	102,458.67
Reserve for Depreciation of Capital of Library	4,000.00
General Reserve	10,000.00
John Fritz Medal (U. E. S. Custodian)	3,500.00
Total	875,677.10
Real Estate Owned by U. E. S. Cost to Dec. 31, 1926	1,973,410.42
Operating Cash and Petty Cash	11,044.95
Accounts Receivable	2,875.76
Value of Library (as Appraised for Insurance)	342,456.00
Total Property for which U. E. S. is Trustee or Custodian	$3,205,464.23

TWENTY-THIRD ANNUAL MEETING

At the twenty-third annual meeting of the United Engineering Society, held in the Engineering Societies Building January 27, 1927 the following officers were elected for the ensuing year: Bancroft Gherardi, Fellow of the American Institute of Electrical Engineers, president; Roy V. Wright, of The American Society of Mechanical Engineers, first vice-president; Francis Lee Stuart, member of the American Society of Civil Engineers, second vice-president; Alfred D. Flinn, member of the American Society of Civil Engineers, secretary; J. S. Langthorn, member of the American Society of Civil Engineers, treasurer and Henry A. Lardner, Fellow of the American Institute of Electrical Engineers, asistant treasurer. The gift of Edward Dean Adams was acknowledged and suitable resolution formulated and passed. Trustees appointed to fill the vacancies created by the expiration of terms were: From the American Society of Civil Engineers, George Gibbs to succeed Lewis D. Rights; from the American Institute of Mining Engineers, Arthur S. Dwight to succeed Walter H. Aldridge; from the American Society of Mechanical Engineers, Roy V. Wright (reelected) and from the American Institute of Electrical Engineers, Calvert Townley to succeed H. H. Barnes, Jr.

J. H. Hunt Elected President of S. A. E.

At the annual dinner and business meeting of the Society of Automotive Engineers held in New York last month, John H. Hunt, of Detroit, head of the electrical division of the General Motors research laboratories and member of the Institute, was elected president of the society for 1927. W. G. Wall of Indianapolis, consulting engineer, was elected first vice-president, and C. B. Whittelsey of Hartford, Conn., president of the Hartford Rubber Works Co., was elected treasurer to succeed himself.

Second vice-presidents elected were; to represent motor car engineering, F. M. Zeder, of Detroit; to represent tractor engineering, J. F. Max Patitz, of Milwaukee; to represent aeronautic engineering, E. T. Jones, of Paterson, N. J.; to represent marine engineering, P. G. Zimmerman, of West Mystic, Conn., and to represent stationary internal combustion engineering, C. B. Jahnke, of Beloit, Wis.

Changes Recommended for Ignition Systems

As the result of a series of tests on ten automotive ignition systems, several modifications of the systems now in use in the automotive industry are suggested for the benefit of manufacturers of spark generators. The report is issued by the National Advisory Committee for Aeronautics, through the Department of Commerce. The tests were run at the Bureau of Standards. Both high-tension magnetos and battery coil systems were studied. The full range of automotive practise was included, both from the standpoint of mechanical condition and endurance of the systems.

PERSONAL MENTION

E. W. Allen, Fellow of the A. I. E. E., has been promoted from the position of manager of the engineering department of the General Electric Company, Schenectady, to that of vice-president in charge of engineering.

Theodore Beran, who has been manager of the New York district area for the General Electric Company since 1903, was recently elected a commercial vice-president. Mr. Beran joined the Institute in 1902.

Samuel M. Kennedy, vice-president of the Southern California Edison Company in charge of business development and public relations, has retired from active service. He has been with the company since 1903 and has been on the membership list of the Institute since 1911.

Henry Duvall James has been elevated to the position of consulting control engineer of the Westinghouse Electric & Mfg. Co., East Pittsburgh, and Edward Brown Nevill has been appointed to succeed him as manager of the control engineering department. Mr. James has been a Fellow of the Institute since 1912 and Mr. Nevill joined during the past year as an Associate.

J. A. Cranston, who has been employed by the General Electric Company ever since it was organized in 1892, has been elected a commercial vice-president. He was manager of the Portland office from 1900 to 1919, northwest manager from 1919 to 1923 and Pacific Coast Manager from 1923 to 1926. He joined the Institute in 1908.

Harry Reid, who has been prominent in public utility activities in Kentucky and the Middle West for twenty years and president of the Interstate Public Service Company since 1917, was recently elected president of the National Electric Power Company with headquarters in New York City. Mr. Reid became an Associate of the Institute in 1922.

Ernest Van Arsdell has been elected president of the Interstate Public Service Company to succeed Mr. Reid, just elected president of the National Electric Power Company. Mr. Van Arsdell was operating manager, and later, vice-president of the Interstate, which has its headquarters in Indianapolis. He joined the Institute in 1923.

Alexander A. Leeven, former squad leader for the electrical engineering department of the Electric Bond and Share Company, 65 Broadway, New York City, assumed his new duties as electrical engineer of the Harrisburg Light and Power Company, Harrisburg, Pa., March 1, 1927. Mr. Leeven was elected an Associate of the Institute in 1924.

Ethan Viall, former editor of the *American Machinist*, and member of the Institute, has taken the position of editor of *Motor Service*, Chicago. Mr. Viall resigned from the *American Machinist* four years ago to devote his time to writing technical books. This work completed, he has decided to return once more to the editing field, in which he has spent nearly 20 years.

Obituary

Russell Robb, senior vice-president and treasurer of Stone & Webster, Inc., and, since 1895, a Member of the Institute, died February 15 at Phillips House, Boston, after a brief illness of one week. Born at Dubuque, Ia., he was graduated from the Massachusetts Institute of Technology in 1888. For three years he was in the engineering service of the Thomson Electric Welding Company at Lynn, Mass., but left it in 1891 to join the engineering organization of Stone & Webster at Boston. He had been a classmate of both C. A. Stone and Edwin S. Webster in the Electrical Engineering course at M. I. T. In 1905 he was made a member of the firm and in 1920 became senior vice-president and treasurer of the company. He was an officer and director of many public utilities in the traction, light and power field and as early in his career as 1896, brought out the book "Electric Wiring." During the period 1909-11, he was lecturer at Harvard University on public utility topics and his Lectures on Organization were privately printed in 1909. Mr. Robb, in his pioneer association with the firm of Stone & Webster, was known throughout the public utility industry as a wise leader, kindly and modest in disposition and much beloved by all those with whom he came in contact. He was prominent also in the civic life of his home town, Concord, Mass., serving as trustee of its public library and a member of many technical and social clubs. He was also a director of many business interests from Cape Breton to El Paso and from the Puget Sound to Key West.

Richard J. Crandall, technical writer, engineering department of the National Lamp Works of the General Electric Company, Nela Park, Cleveland, Ohio, and Associate of the Institute, died at Cleveland January 13, 1927. Mr. Crandall was born at Urbana, Illinois, January 10, 1904. In 1924 he obtained his B. S. degree in Electrical Engineering at the University of Illinois and immediately entered upon his work with the National Lamp Works. He was an active member in the Cleveland Section of the Institute and it is said that despite his great physical handicap, he attended practically every meeting and never missed an inspection trip either in or outside of the city. Mr. Crandall joined the Institute in 1925.

Arthur R. Jealous, assistant works manager of the Clark Thread Company, Newark. New Jersey, and Associate of the Institute, died Saturday January 8, after a two weeks' illness. Mr. Jealous was born June 19, 1885 and was a graduate of Massachusetts Institute of Technology (1907). In 1909 he became assistant to the electrical engineer of the American Woolen Company, remaining with these interests until 1912. He then was made commercial engineer in the mill power department of the General Electric Company at Boston. In 1914 he joined the Clark Thread Company in the capacity in which he was serving it at the time of his death.

Samuel Owen Edmonds, an Associate of the Institute since 1903, died suddenly the morning of January 20, 1927. Mr. Edmonds was a native of Pottsville, Pennsylvania. Supplementing his general grammar and high school education by three years private tutelage in Washington, D. C., he acquired his technical education by the study of electrical literature, and the processes and various apparatus in shops and central stations, devoting no inconsiderable portion of his later time to the specific study of patent litigations; in fact for fifteen years prior to his joining the Institute, he gave his time almost exclusively to the subject, counting among his many clients Thomas A. Edison, General Electric Company, the Gamewell Fire Alarm Telegraph Company, and the Municipal Signal Company. At the time of his death, Mr. Edmonds was practising law at 233 Broadway, New York City, in his own offices.

Earl A. Shaefer, designing engineer for the General Electric Company, Fort Wayne, Ind., died at his desk there the latter part of January 1927. Mr. Shaefer was born in Wells County, Ind. and was graduated from the Electrical Engineering course of Purdue University in 1913. He immediately joined the Student Course of the General Electric Company and took up the work of design engineer. Mr. Shaefer was elected an Associate of the Institute in 1922.

William Korff, who was supervising engineer of the transmission engineering department of the Southern California Telephone Company, Los Angeles, Calif., died early in January 1927. Mr. Korff was born in Rochester, N. Y. November 10, 1889 and received his technical education at Columbia University New York City. In 1912 he went into the test department of the General Electric Company as New York engineer, but in 1915 gave up his work there to join the Edison Illuminating Company as its Detroit representative in engineering. He was next City Electrical Engineer at Royal Oak, Michigan in 1921, and in 1923, joined the company of his last affiliation, the Southern California Telephone Company and Pacific Tel. and Tel.

Company at Los Angeles, for whose interests he did much valuable work. Mr. Korff became an Associate of the Institute in 1925.

Charles C. Stutz, consulting engineer, New York City, and identified with the Institute since 1900, died suddenly Saturday, January 29th, at his home, West End Avenue, New York. Mr. Stutz was born at Naples, Italy, in 1861, he came to this country when he was 21 years old. Prior to that time he had taken a full course in mechanical engineering at the Polytechnic School at Zurich, Switzerland, with a side course in electrical subjects. For five years he was assistant to the chief draftsman of the Brown & Sharpe Mfg. Co., at Providence, R. I., and for three and a half years, chief engineer and superintendent for an Alsatian Company employing 650 men, building machine tools, steam engines, dynamos, arc lights and smaller electric light installations. For two years thereafter he was in charge of the special design and manufacture of electric elevator equipment for the Central London Railway of the Sprague Electric Company, remaining with the Sprague Electric interests until he established his own consulting practise in this city.

Past Section Meetings

SECTION MEETINGS

Boston

Research and Invention, by S. M. Kintner, Westinghouse Elec. & Mfg. Co., January 20. Attendance 150.

The Electrical Installation in Hotel Statler, Boston, by Karr Parker, Consulting Engineer. Joint meeting with I. E. S. January 28. Attendance 450.

Chicago

Power for Transportation in Chicago, by H. B. Gear, Commonwealth Edison Co. Joint meeting with Electrical Section of W. S. E. January 17. Attendance 600.

Cincinnati

Lightning and High-Voltage Phenomena, by F. W. Peek, Jr., General Electric Co. Illustrated with slides and motion pictures. December 7. Attendance 120.

Elevator Design and Practise, by H. B. Cook, Warner Elevator Mfg. Co. January 13. Attendance 35.

Cleveland

High-Capacity Mercury Arc Rectifiers, by D. C. Prince, General Electric Co. Illustrated with slides. January 20. Attendance 90.

Denver

Construction and Characteristics of X-Ray Apparatus, by Dr. K. D. A. Allen, Roentgenologist of the Presbyterian Hospital Staff. Demonstrated. February 4. Attendance 42.

Detroit-Ann Arbor

Use of Graphic Instruments, by J. W. Esterline, Esterline Angus Co. A dinner preceded the meeting. January 18. Attendance 75.

Erie

Evolution of the Automatic Telephone, by James Engh, Automatic Electric Co. Illustrated with slides. January 18. Attendance 205.

Fort Wayne

Mountain Making, by F. B. Taylor, Geologist. Illustrated with slides. January 20. Attendance 65.

Indianapolis-Lafayette

Recent Advances in the Art of Communication, by M. B. Long, Bell Telephone Laboratories. Accompanied by stereoptican views and moving pictures. January 10. Attendance 108.

Kansas City

Financing, Construction and Operation of the Panhandle Power and Light Co., by Chester Smith, Edwin Jewett, R. L. Frisby and A. E. Bettis. Joint with A. S. M. E. January 18. Attendance 105.

Los Angeles

Engineering in the Navy, by Commander O. L. Cox. To augment the talk a motion picture, entitled "Queen of the Waves," was shown.

The Use of the Kilowatt-Kilowatthour Curve in Economically Operating Hydro and Steam Plants, by A. Wilstam, Southern California Edison Co. A dinner preceded the meeting. February 1. Attendance 133.

Lynn

Electricity in Rail and Land Transportation, by H. L. Andrews, General Electric Co. Illustrated with slides. A short talk on this subject was also given by W. B. Potter, General Electric Co. January 26. Attendance 95.

Madison

Lightning Arresters, by A. L. Atherton, Westinghouse Elec. & Mfg. Co. Illustrated with slides. A motion picture, entitled "White Coal," was also shown. January 17. Attendance 35.

Minnesota

Lighting the Sesquicentennial Exposition, by D. W. Atwater, Westinghouse Lamp Co. Illustrated with slides. January 18. Attendance 70.

Nebraska

Air-Mail Problems, by D. B. Colyer, U. S. Air Mail Service. December 9. Attendance 37.

Safety Removable Truck-Type Switchboards, by C. C. Adams, General Electric Co. Demonstrated. Motion pictures, entitled respectively "Modern Truck Type Switchboards" and "Supervisory Control," were shown. January 25. Attendance 25.

Philadelphia

Recording and Analysis of Power Transients in Transmission Systems, by C. F. Wagner, Westinghouse Elec. & Mfg. Co. Illustrated with slides. December 13. Attendance 135.

Underground Transmission at 75,000-Volts in Philadelphia, by H. S. Phelps and J. W. Sylvester, Philadelphia Electric Co. Illustrated with slides and motion pictures. January 10. Attendance 235.

Pittsburgh

Large Turbo Generator Development, by L. T. Peck, American Brown Boveri Electric Corp.; W. B. Spellmeyer, General Electric Co., and F. D. Newbury, Westinghouse Elec. & Mfg. Co. Joint meeting with Electrical Section of Engineering Society of Western Pennsylvania. January 11. Attendance 332.

Pittsfield

The Quest of the Unknown. A Round-Table Discussion under the leadership of Prof. H. B. Smith, Worcester Polytechnic Institute. Illustrated with slides. January 14. Attendance 50.

Unusual Uses of Wood, by Arthur Koehler, University of Wisconsin. A number of specimens were displayed. January 18. Attendance 250.

Romance and Tragedy in Modern Horticulture, by E. I. Farrington, Massachusetts Horticultural Society. Illustrated with slides. February 1. Attendance 200.

Rochester

Diverter-Pole Generator, by E. Darwin Smith, Jr., Rochester Electric Products Corp. Illustrated by charts and portions of the machine. January 14. Attendance 60.

St. Louis

Hallow-e'en Party. October 30. Attendance 68.

Banking of Transformers, by M. T. Mitschrich, Moloney Electric Co. January 19. Attendance 51.

Schenectady

Industrial Conditions, by R. M. Davis, McGraw-Hill Co. Illustrated with slides. January 21. Attendance 150.

Seattle

The Diablo Development of the Skagit River, by J. D. Ross, City Light Dept. Illustrated with slides. December 21. Attendance 77.

Recent Advances in Electrical Communication, by L. S. O'Roark, Bell Telephone Laboratories, Inc. Illustrated with slides and motion pictures. Demonstrated with an electromagnetic phonograph. January 18. Attendance 185.

Sharon

The Pymatuning Dam, by Ralph J. Ferris and Fred T. Fruit. February 1. Attendance 110.

Southern Virginia

State Highway Construction, by H. G. Sherley,

Present Tendencies in Power-Station Design, by V. E. Alden, Stone & Webster, Inc., and

Activities of American Engineering Council, by L. W. Wallace, Secretary, A. E. C. All-day joint meeting with A. S. M. E., A. S. C. E. and the Engineer's Club of Hampton Roads. The following officers were elected: Chairman, W. S. Rodman; Secretary-Treasurer, J. H. Berry. January 21. Attendance 66.

Spokane

Recent Advances in Electrical Communication, by L. S. O'Roark, Bell Telephone Laboratories. Illustrated with slides, motion pictures and phonograph records. January 10. Attendance 103.

Electrification, by P. A. McGee, Westinghouse Elec. & Mfg. Co. January 28. Attendance 50.

Springfield

A talk was given by C. C. Chesney, National President, A. I. E. E., in which he described his trip through the western states and along the Pacific Coast. Illustrated with slides. January 18. Attendance 150.

Toledo

A talk was given by L. W. Wallace, Secretary of the American Engineering Council, who outlined the work that has been done and is being done by the A. E. C. Dean Kimball, Cornell University and President of the A. E. C., touched on the highlights of engineering progress and its relation to economics. A dinner preceded the meeting. January 25. Attendance 100.

Toronto

The Electron Theory, by Professor E. F. Burton, Toronto University. By the use of special apparatus many demonstrations were given. December 17. Attendance 85.

Technical and Economic Analysis of Electric Power Transmission, by G. D. Floyd, Hydro-Electric Power Comm. of Ontario. January 14. Attendance 101.

Voltage Regulation, by J. H. Ashbaugh, Westinghouse Elec. & Mfg. Co. Illustrated with slides and diagrams. January 28. Attendance 74.

Urbana

The Manufacture and Application of Carbon Products, by E. A. Williford, National Carbon Co. January 14. Attendance 40.

Vancouver

Recent Advances in Electrical Communication, by L. S. O'Roark, Bell Telephone Laboratories. January 14. Attendance 140.

Pier B. C. of the Canadian-Pacific Railway Co., by S. C. Gale, student, University of B. C.;

Graduate's Course at C. G. E. Co. Works, by F. R. Barnsley, student;

Air Brakes, by J. W. Millar, student;

Radio Telegraph Transmission, by J. T. North, student, and

Modern Methods of Heating and Ventilation, by C. W. Leek, student. February 1. Attendance 34.

Washington

Electric Drive for Battleships, by Admiral R. S. Griffin, U. S. N. Joint with Washington Society of Engineers. February 8. Attendance 220.

Worcester

Industrial Conditions, by R. M. Davis, McGraw-Hill Co. The meeting was preceded by a dinner. January 4. Attendance 25.

A. I. E. E. Student Activities

ELECTRICAL SHOW AT MICHIGAN STATE COLLEGE

The annual Electrical Show at Michigan State College, put on by the students in the Electrical Engineering Department, was held Feb. 1-3 inclusive, during Farmers' Week at the college.

Exhibits consisted largely of electrical apparatus constructed by the students themselves for use in demonstrating electrical phenomena. A complete miniature railway, controlled by the automatic block system, was shown in operation; also other examples of the work of the students. The a-c. and d-c. machines and laboratories were open to inspection by the public, students acting as guides for all displays. Commercial exhibits showing the latest developments in electrical appliances and home lighting were also on display.

Approximately 8000 visitors attended the show and the students received many compliments upon the exhibition, from both the visitors and the faculty.

STUDENT PROGRAM AT MEETING OF VANCOUVER SECTION

At a meeting of the Vancouver Section held on February 1, 1927, the following papers were presented by seniors in electrical and mechanical engineering at the University of British Columbia:

Pier B. C. of the Canadian Pacific Railway Company, by Stanley C. Gale.

Graduates' Course at the Canadian General Electric Company Works, by Frank R. Barnsley.

Air Brakes, by James W. Millar.

Radio Telegraph Transmission, by John T. North (Enrolled Student, A. I. E. E.)

Modern Methods of Heating and Ventilation, by Charles W. Leek.

The program was thoroughly appreciated by all present, and the Section officers think the plan is worthy of repetition next year.

BRANCH MEETINGS

Municipal University of Akron

Power Factor Problems, by Frank Wallene. January 14. Attendance 62.

Alabama Polytechnic Institute

Merchandising, by Mr. Williamson, Mathew's Electric Co., and

Advertising, by Mr. Smith, Mathew's Electric Co. January 19. Attendance 28.

History of the Electrical Industry, by Prof. W. W. Hill. February 3. Attendance 41.

University of Arkansas

Cathode Ray Tubes, by Tony Spitzberg, student. December 21. Attendance 11.

Automatic Telephone, by Hartman Reigler, student. January 18. Attendance 21.

Armour Institute of Technology

Electrical Communication, by M. B. Long, Bell Telephone Laboratories, Inc. January 13. Attendance 80.

Motion pictures entitled respectively "Queen of the Waves," "The Electrical Giant" and "Revelations by the X-Ray" were shown. January 20. Attendance 50.

Carnegie Institute of Technology

Radio-Broadcast Transmission Methods, by J. B. Colman, Westinghouse Electric & Mfg. Co. Illustrated with slides. January 12. Attendance 30.

Case School of Applied Science

Life and Work of Robert Norman, by J. L. Whiteman, student;

Life and Work of William Gilbert, by K. Sherman, student, and

Life and Work of Benjamin Franklin, by W. F. Reeder, student. February 5. Attendance 56.

Clarkson College

Personal Hygiene, by Dr. R. J. Reynolds, U. S. Army. January 4. Attendance 138.

Clemson College

Electric Heat used in Manufacturing Processes, by F. J. Fishburne;

Super Power Installations in the United States, by E. P. Hafers, and

New Cathode Ray Tube Developed by Dr. W. D. Coolidge, by L. D. Gaston. February 10. Attendance 10.

Colorado Agricultural College

Business Meeting. Mr. Harold Groat was elected Secretary-Treasurer. January 31. Attendance 13.

University of Colorado

Recent Developments and Accomplishments of Last Year, by A. L. Jones, General Electric Co., and

Opportunities for G. E. Graduates, by M. M. Boring, General Electric Co. January 5. Attendance 55.

Some Factors of Power Development in Colorado, by H. H. Kerr, Public Service Co. January 26. Attendance 35.

Cooper Union

Electric Railway Signalling, by H. T. Wilhelm, Chairman of the Branch. January 14. Attendance 70.

University of Denver

Construction of a 110-Kv. Transmission Line, by C. Connor, and

Status of Electrical Lighting in 1926, by L. Booth. February 4. Attendance 14.

Drexel Institute

Machine Switching Telephone Systems, by R. S. Eininger, Jr., Secretary of the Branch. January 14. Attendance 26.

University of Florida

Mechanical Stokers. Illustrated lecture. Joint meeting. January 13. Attendance 16.

Transmission Line and Street Lighting Equipment, by L. H. Messinger, Line Material Co. The lecture was supplemented by an exhibition of samples of the various types of equipment. February 7. Attendance 16.

University of Idaho

Motion pictures, entitled respectively "Magic of Communication" and "Auxiliary Products of Telephone Research," were shown. January 7. Attendance 61.

General Features of the Construction of the Lake Chelan Project, by Carl Clair, student, and

History of the Electric Light, by Clifford Morgan, student. January 20. Attendance 20.

Iowa State College

Business Meeting. January 11. Attendance 18.

The Commercial Application of an Engineering Education, by E. Wanamker, Chicago, Rock Island and Pacific Railroad. A dinner preceded the meeting. January 26. Attendance 202.

Kansas State College

The Work and Opportunities for Electrical Graduates with Some of the Large Manufacturing and Public Utilities Companies, by Prof. C. E. Reid. January 17. Attendance 85.

University of Kansas

Powdered Coal, by H. W. Brooks, Fullerton, Pa. Joint meeting with A. S. M. E. The following officers were elected: Chairman, Elmer Bayles; Vice-Chairman, Delbert Stoltenberg; Secretary, Miss Lottye Young; Treasurer, Graham Oldham. January 13. Attendance 60.

Lafayette College

Electricity in the Modern Cement Plant, by Mark R. Woodward, Lehigh Portland Cement Co. The meeting was followed by an inspection trip through the plant of this company located at Martins Creek. January 12. Attendance 26.

Lehigh University

The Conowingo Power Project, by N. E. Funk, Philadelphia Electric Co. Illustrated with slides. Joint meeting with A. S. C. E. January 20. Attendance 118.

Lewis Institute

Business Meeting. January 11. Attendance 23.

Oxygen, by G. E. Harcke, Air Reduction Sales Co. Illustrated. The Branch received an invitation from the Commonwealth Edison Company to attend the Power Show and Conference, February 15, 16 and 17. January 25. Attendance 283.

Business Meeting. February 8. Attendance 17.

Louisiana State University

Lake Front Development of New Orleans, by Colonel Garsand. January 26. Attendance 100.

University of Maine

A Few Points of Interest at the I. R. E. Convention in New York, by Dean Cloke. A motion picture on the Telephone was shown. January 13. Attendance 38.

Marquette University

A Study of Transverse Reactions in Synchronous Machines by the Use of Booster Transformers, by Clifford Earle, student. This was a report, illustrated by diagrams, on his experimental work.

Determination of Transverse Reaction Constants in Synchronous Machines by the Use of a Movable Stator Testing Machine, by Roman Schaefer, student. He reported from experimental tests. December 30. Attendance 12.

The Economic Advantages of Education, by R. L. Cooley, Dean of the Milwaukee Continuation School. Joint meeting with the Engg. Association of the College of Engg. January 13. Attendance 310.

Massachusetts Institute of Technology

Four Practical Engineering Problems, by R. H. Rogers, General Electric Co. January 12. Attendance 50.

Michigan State College

Business Meeting. January 11. Attendance 24.

School of Engineering of Milwaukee

Inspection trip to Bay View Plant of the Illinois Steel Mills. February 3. Attendance 35.

Electric Arc Welding, by C. L. Hansen, North Western Mfg. Co. February 8. Attendance 20.

University of Minnesota

Flood-lighting the Sesqui-Centennial Exposition, by D. A. Atwater, Westinghouse Elec. & Mfg. Co. Joint meeting with Minnesota Section. January 18. Attendance 80.

Operation of a Steam Plant and Its Relation to an Interconnected System, by J. A. Colvin, Northern States Power Co., and

New Developments in the Modern Central Station, by Prof. C. F. Shoop. Joint meeting with A. S. M. E. January 24. Attendance 300.

University of Missouri

Problems of the Industrial Electrical Engineer, by V. A. Snow, student, and

Summer Experiences with Westinghouse Electric & Mfg. Company, by Harold Elzie, student. February 7. Attendance 33.

Montana State College

Heat Dissipation from Transformer Vaults, by O. B. Putnam, and

Electricity from Light, by Harold Rivenes. January 6. Attendance 181.

The Largest Storage Battery Locomotive, by W. F. Kobbe, and

The Radio Amateur, by Dennis Johnson. January 20. Attendance 176.

A motion picture, entitled "The Single Ridge," was shown. February 10. Attendance 211.

University of Nebraska

Super Power, by T. A. Lee, Nebraska Gas and Electric Co. Dinner Meeting. Tickets were sold to all engineers. February 2. Attendance 75.

Newark College of Engineering

Members of the Branch attended the Meeting of the New York Sections of the A. I. E. E. and the A. S. M. E., held at the Public Service Terminal in Newark, at which the Kearny and East River Power Stations were discussed. January 19. Attendance 40.

The Engineer after Graduation, by E. B. Meyer, Public Service Production Co. Illustrated with slides. February 2. Attendance 20.

University of New Hampshire

Steam Turbine Practise and *Power Plant Problems*, by Mr. Richardson, General Electric Co. January 5. Attendance 44.

Opportunities Offered by the Lowell Electric Light Corp. to Engineering Graduates, by Mr. McKinley. January 12. Attendance 49.

A motion picture, entitled "Westinghouse Works," was shown. January 19. Attendance 41.

Direct Current Generators and Motors, by E. F. Lafond, student, and

The Moore Tube, by R. O. Maloney, student. January 26. Attendance 38.

Electroplating, by L. L. Landon, student, and

History of Telephones, by H. T. McRae, student. February 2. Attendance 36.

A motion picture, entitled "Behind the Pyramids," was shown. February 9. Attendance 41.

College of the City of New York

Business Meeting. The following officers were elected: Faculty Chairman, Prof. Harry Baum; Student Chairman, Harold Wolf; Vice-Chairman, Joseph Leipziger; Secretary, Adolph H. Rapport; Treasurer, E. F. Day. January 20. Attendance 10.

University of North Carolina

Watthour Meters, by John Cantwell. Illustrated with slides. January 13. Attendance 30.

Dam Construction, by Mr. Meis, Consulting Engr., and

Development of the Modern Transformer, by Mr. Griffin and Mr. Hazel. January 27. Attendance 33.

Industrial Heating, by W. N. Michal. Illustrated. A motion picture, contrasting the old and new kitchen equipment, was shown. The following officers were elected: President, H. E. Thompson; Vice-President, G. M. Wilson; Secretary, W. N. Michal; Treasurer, W. A. Baxter, February 10. Attendance 25.

University of North Dakota

Transformers and Instruments, by Mr. Wilms, General Electric Co. Illustrated. January 18. Attendance 46.

BTA-Alternating Current Commutator Motor. Illustrated lecture. January 24. Attendance 14.

Northeastern University

A talk was given by Prof. R. G. Porter upon the events at the recent I. R. E. Convention. He discussed the papers that were presented. In addition, Prof. Porter gave a description, with the aid of pictures, of the transoceanic telephone apparatus. January 11. Attendance 25.

Ohio University

Business Meeting. January 12. Attendance 9.

Business Meeting. The following officers were elected: Chairman, Clarence Kelch; Vice-Chairman, Minola Mariner; Secretary-Treasurer, Glen R. Smith. The members adjourned to hear the paper on Concrete Bridge Construction given by Prof. N. D. Thomas before Pi Epsilon Mu. January 19. Attendance 14.

Ohio Northern University

The Central Stations and Sub-Stations of the Ohio Power Company, by M. W. Heft, Chairman of the Branch. January 20. Attendance 33.

The Commercial Methods of Motor Testing, by John Simmons. February 3. Attendance 31.

Ohio State University

The Motor Fuel of the Future, by Mr. Trusdale, Petroleum News of Cleveland, and

Possibilities of the Diesel-Electric Locomotive, by N. W. Storer, Westinghouse Elec. & Mfg. Co. The meeting was broadcast by WEAO, the Ohio State University Broadcasting Station. January 21. Attendance 204.

Steam Road Electrification, by J. J. Limbaugh, General Electric Co. Illustrated with slides. January 28. Attendance 50.

Oregon Agricultural College

Diesel-Electric vs. Trolley Electrified Railroads, by C. G. Archibald and H. M. Dalby. Motion pictures were shown, illustrating the making of telephone cable, the operation of the telephone circuit, the development of railways and the applications of electrified railways. January 11. Attendance 42.

Pennsylvania State College

Mine Electrification, by Prof. W. R. Chedsey. January 12. Attendance 22.

University of Pittsburgh

India As It Stands Today, by M. R. Malhotra, student, and

From Immigrant to Inventor, by H. H. Brooks, student. January 7. Attendance 28.

Carbon Monoxide Poisoning and Its Treatment, by W. P. Yant, U. S. Bureau of Mines. Joint meeting. January 14. Attendance 100.

Photo-Micrography, by J. A. Wehrle. January 21. Attendance 28.

Rhode Island State College

How We Should Spend Our Leisure Time, by Mr. Bragg, student. December 15. Attendance 15.

Gas-Electric Busses and Turbo-Generator Manufacturing, by O. C. Larson, student. Illustrated. January 12. Attendance 14.

A motion picture, entitled "Single Ridge," was shown. January 19. Attendance 33.

Frequency, by H. V. VanValkenburg, student. January 26. Attendance 11.

South Dakota State School of Mines

A motion picture, entitled "The King of the Rails," was shown. January 14. Attendance 125.

University of South Dakota

Mercury Arc Rectifiers, by Mr. Shattuck. January 12. Attendance 13.

Transformers, by Mr. Hazelton, General Electric Co. Illustrated. January 19. Attendance 31.

Business Meeting. February 9. Attendance 14.

Swarthmore College

Criticism of Engineers, by Errol Doebler, Assistant Professor of Civil Engineering. The speaker said that engineers as a whole do not deal with the public enough. January 17. Attendance 18.

Agricultural and Mechanical College of Texas

Electricity Connected with Coal Mining, by E. H. Mittanck;

The Rectifier, by E. J. Allen;

Illumination, by W. T. Clark, and

Accidents, by R. B. Webb. January 7. Attendance 90.

University of Utah

The Colorado River Project, by Ralph Wooley, a member of the Governor's Advisory Board of the State of Colorado. Illustrated with maps. Joint meeting. January 11. Attendance 60.

Virginia Polytechnic Institute

The Bell System, by a representative of the A. T. & T. Co. The motion picture, entitled "The Magic of Communication," was also shown. January 20. Attendance 172.

University of Virginia

Business Meeting. February 1. Attendance 8.

Washington and Lee University

A motion picture, entitled "Electrification of Railways," was shown. January 14. Attendance 11.

State College of Washington

Business Meeting. January 27. Attendance 15.

Washington University

The Oil-Electric Locomotive, and *Australia and Its Railroads*, by R. T. Sawyer, General Electric Co. Accompanied by a motion picture. February 3. Attendance 30.

University of Wisconsin

Lightning Arresters, by A. L. Atherton, Westinghouse Electric & Mfg. Co. January 17. Attendance 50.

Worcester Polytechnic Institute

Problems Confronting the Engineer in Railway Electrification, by Sidney Withington, New York, New Haven and Hartford Railroad. Illustrated with slides.

The Advantages of A. C. Electrification as Compared with D. C. Electrification, by R. L. Kimball, Westinghouse Electric & Mfg. Co. A motion picture, entitled "An Electrified Travelog," was also shown. January 21. Attendance 83.

University of Wyoming

A Cable Splicer, by W. E. Bond, Mountain States Telephone & Telegraph Co. Demonstrations. November 4. Attendance 34.

Motion pictures, entitled respectively, "Land of the White Cedars, "Laying the World's Fastest Cable," and "Something about Switchboards," were shown. November 18. Attendance 133.

The Electrical Power Development in Wyoming, by Oswald Seaverson. December 9. Attendance 17.

Motion pictures, entitled "Getting Out the Goods," "Far Western Cedar Trails," and "The Magic of Communication," were shown. January 13. Attendance 107.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is adminstered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES JANUARY 1-31, 1927

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

APPLIED X-RAYS.

By George L. Clark. N. Y., McGraw-Hill Book Co., 1927. 255 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

This book, which aims to present the possibilities of X-rays as a new tool for industry, is written primarily for the industrial executive or director of research who wishes to understand what this new tool is, how it may be used and what information it may be expected to give on practical problems. It presents the fundamental physics of X-rays and describes their properties, the direct applications of the radiation and the applications to the study of crystalline structure of materials.

AUTOMOBILE.

By Reinhold Thebis. Ber. u. Lpz., Walter de Gruyter & Co., 1926. 107 pp., illus., 6 x 4 in., cloth. 1,50 r. m.

This little work describes with great conciseness the general construction of the gasoline automobile, the motor truck and the electric truck.

BEITRAGE ZUR GESCHICHTE DER TECHNIK UND INDUSTRIE; Jahrbuch des V. D. I., 1926.

By Conrad Matschoss, editor. 354 pp., illus., ports., 11 x 8 in., cloth. 16.-r. m.

The latest of the valuable yearbooks issued by the Society of German Engineers and devoted to the history of engineering, covers an unusually wide range. Distilling, oil-firing, the chemical utilization of wood, lightning rods, coining, calculating machines, electric hoisting machinery are the subjects of historical papers. Biographies of Felix Grashof and Hermann Gruson are included, and there are papers upon two fifteenth century engineers, Biringuccio and Guiliano da San Gallo. Twelfth century engineering is treated in a review of the "Schedula Diversarum Artium" of Theophilus Presbyter. New features this year are abstracts of important articles published elsewhere and an index to the literature of the year.

CHEMICAL ENGINEERING ECONOMICS.

By Chaplin Tyler. N. Y., McGraw-Hill Book Co., 1926. (Chemical Engineering series). 271 pp., charts, tables, 9 x 6 in., cloth. $3.50.

"Virtually all of our attention in the colleges," says Mr. Tyler, "is turned toward the technical side of industrial enterprises, whereas in the actual practise of chemical engineering as a profession, the economic and business considerations usually are controlling." His book is intended to help bridge the gap that separates classroom instruction from industrial practise, by discussing such topics as plant location, layout and design; cost accounting, operating costs, management, fuels, operation and control. The general characteristics and magnitude of the chemical industries are also considered.

DONNEES NUMERIQUES D'ELECTRICITE, MAGNETISME ET ELECTROCHIMIE.

Compiled by A. Buffat and others. (Extrait du vol. 5, Tables Annuelles de Constantes et Données Numeriques). Paris, Gauthier-Villars et cie; Chicago, University of Chicago Press, 1926. 135 pp., tables, 11 x 9 in., paper. Prices for members of the Society, 57.75 fr., cloth; 42 fr., paper. Apply to M. Charles Marie, General Sec'y., 9 Rue de Bagneux, Paris VIe.

For the convenience of those interested only in certain subjects, the publishers of the Annual Tables of Numerical Constants and Data are issuing these volumes in sections. The present publication is an extract from volume 5. It contains the data upon electricity, magnetism and electrochemistry which were published during the years 1917 to 1922, inclusive, with references to the sources. A table of contents in English is provided. Similar separate publications for volumes 3 and 4 are available, including data published between 1912 and 1916.

ELECTRIC TRAINS.

By R. E. Dickinson. N. Y., Longmans, Green & Co.; Lond., Edward Arnold & Co., 1927. 292 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.00.

The aim of this book is to present those matters of primary interest to the railroad engineer without the use of advanced mathematics. Emphasis is therefore placed on the fundamental principles of electric traction, the apparatus in use, similar matters related to the running and maintenance of trains, while matters relating to the generation, transmission and transformation of electric power have been omitted.

ELEKTRISCHES SCHALTZEUG.

By Ernst Schupp. Ber. u. Lpz., Walter de Gruyter & Co., 1927. (Siemens-Handbucher, bd. 7). 179 pp., illus., diagrs., 8 x 6 in., cloth. 5,40 r.m.

A descriptive handbook of starting and regulating apparatus, switches and switchboards, based upon the types manufactured by the Siemens-Schuckert works. The construction of the types is described in detail, and the proper method of using and caring for them are explained. The book is intended to facilitate the selection of correct equipment for any given purpose and also to guide the inexperienced user.

ELECTRIC POWER STATIONS.

By L. W. W. Morrow. N. Y., McGraw-Hill Book Co., 1927. 326 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

Mr. Morrow's book treats the question of the production, transmission and distribution of electrical energy on a large scale from a broad viewpoint. Leaving to the specialist the separate details of the elements of the problem, he discusses the principles, as exemplified by present practice and opinion, which guide the engineer and the executive in the selection of equipment and its assemblage at different locations along the stream of electrical energy, so that this energy may be produced and carried to the consumer efficiently and economically. He tries to coordinate the different engineering principles and the variety of equipment and to weigh the respective elements in relation to the whole system.

EMPLOYMENT STATISTICS FOR THE UNITED STATES. Edited by Ralph G. Hurlin and William A. Berridge. N. Y., Russell Sage Foundation, 1926. 215 pp., forms, 9 x 6 in., cloth. $2.50.

In 1922 the American Statistical Association undertook a study of methods for collecting and presenting statistics on employment, with the object of removing the unsatisfactory character of the statistics available hitherto. The committee, consisting of a representative body of experts, has studied the various uses for employment statistics, the methods of procedure

in gathering and checking them, the forms of records, and the methods of analysis and presentation in current use; and presents its conclusions in this report.

Erdstatische Berechnungen Mit Reibung und Kohasion.

By W. Fellenius. Berlin, Wilhelm Ernst & Sohn, 1927. 40 pp., diagrs., 10 x 7 in., paper. 4,20 r. m.

In calculating problems dealing with earth pressures and similar problems of geostatics it has been customary to consider only the frictional resistance of the earth and to assume that the sliding surfaces were plane. Recent investigations, however, have shown the desirability, in certain cases, of calculations based upon the presence of curved surfaces and upon also taking account of the cohesion, or rather adhesion, of the soil. Professor Fellenius here presents the results of an investigation of this problem and gives a method for the systematic calculation of cases that include these assumptions. The methods of calculation set forth are, he states, particularly important in calculations of the stability of slopes, for quays and fills on unstable earth, and in the investigation of landslides.

Fluglehre.

By Richard Von Mises. 3rd edition. Berlin, Julius Springer, 1926. 321 pp., diagrs., tables, 8 x 5 in., paper. 12,60 r. m.

An elementary text dealing with the mechanical principles underlying present methods of flight. The book discusses the resistance of the air, supporting surfaces, gliding, aerofoils, motors, steering, stability, flying, landing, etc. Higher mathematics is avoided and the book may be understood by those without college training.

The work is based on courses of instruction given to student officers in the flying corps of the German army in 1913 and 1916.

Georg Agricola, 1494-1555. By Ernst Darmstaedter. 96 pp., illus., port.

Berg-, Probir- Und Kunstbuchlein. By Ernst Darmstaedter. 206 pp., illus.

Munchen, Verlag der Munchner Drucke, 1926. 2 v. (Munchener Beitrage zur Geschichte und literatur der naturwissenschaften und medizin; heft 1 & heft 2/3). 9 x 6 in., paper. Heft 1, 6,-mk.; Heft 2/3, 7,-mk.

These attractively printed monographs are the first of a series upon the history and literature of the natural sciences and medicine, to be published at irregular intervals. Each of the series is to be devoted to a particular period or an important individual. A historical sketch of the period or an estimate of the individual will be given, together with an accurate bibliography of first editions and principal writings.

The monograph on Agricola contains a brief outline of his life, a detailed summary of the contents of his principal works, a bibliography and a list of references to literature about him. It is illustrated by reproductions of title pages and of illustrations from "De re metallica."

The second pamphlet deals with the small handbooks on mining, assaying and alchemy. These were chiefly books of recipes, practical hints, etc. They began to appear about 1505 and were published in many editions during the sixteenth to the eighteenth centuries.

The development of mining and assaying, as shown by these books, is here discussed, and an extensive bibliography is given. Both books will interest students of early engineering.

Geschiebebewegung in Flussen und an Stauwerken.

By Armin Schoklitsch. Wien, Julius Springer, 1926. 108 pp., illus., diagrs., tables, 10 x 6 in., paper. 8,70 r. m.

Presents the results of extensive experiments and observations upon silting in streams and storage reservoirs. The author has investigated many questions of importance to the engineers of water power developments. The investigations were carried out in the hydraulic laboratory of the Graz Technical High School and compared with measurements and observation on water-power plants near-by. The report is illustrated by many interesting photographs.

High Vacua.

By G. W. C. Kaye. Lond. & N. Y., Longmans, Green & Co., 1927. 175 pp., illus., 9 x 6 in., cloth. $3.75.

This work contains useful practical information on the methods used in research laboratories and industrial plants for producing high vacua. The book opens with a historical chapter, followed by one on electrical discharges in vacuum tubes. The technique of vacuum work and the construction of tight joints are discussed, after which the various types of pumps are described. Other topics are: absorption methods of exhaustion, high-vacuum gages and the measurement of pump speeds.

Highway Administration and Finance.

By Thomas R. Agg and John E. Brindley. N. Y., McGraw-Hill Book Co., 1927. 382 pp., diagrs., tables, 9 x 6 in., cloth. $4.00.

A textbook on the administrative duties of state or municipal highway departments. The authors give an account of the establishment and development of highway administration in America and discuss the financing of highway projects, the functions of highway departments, the organization of the staff and similar topics. The work is intended to serve as a basis for the study of the management and economic phases of highway engineering.

Hydroelectric Handbook.

By William P. Creager and Joel D. Justin. N. Y., John Wiley & Co., 1927. 897 pp., illus., diagrs., maps, tables, 9 x 6 in., fabrikoid. $8.00.

In preparing this reference book the contributors have aimed to present, in the usual "handbook" form, a compendium of practice and theory covering all phases of hydroelectric work. The factors which determine the power available in a stream are discussed, the general design of the hydraulic plant and the design of dams, canals, flumes and pipes are treated. Special chapters treat of the substructure and superstructure of the powerhouse and the turbines. The electrical design and equipment, and transmission lines are then taken up. The volume closes with chapters on investigations and reports, on river gaging and on the operation of hydroelectric properties.

Introduction to Metal Work.

By T. R. Parsons. Lond., E. & F. N. Spon, 1927. 121 pp., illus., 7 x 5 in., boards. 4 s.

Intended to supplement instruction in manual training. Gives a brief description of the methods of extracting the common metals from their ores, the changes that occur in heat treating, the handling of tools and the methods of forging, turning, etc.

Les Machines Asynchrones.

By Richard Langlois. Paris, Dunod, 1926. 268 pp., diagrs., 10 x 6 in., paper. 38 fr. 50.

An extensive study of the theory and applications of asynchronous motors, by an experienced designer. Intended as an introduction to the subject, for use by those who are not specialists, or as the preliminary to specialized study.

Principles of Modern Radio Receiving.

By L. Grant Hector. Buffalo, N. Y., Burton Publishing Co., 1927. 305 pp., illus., diagrs., 9 x 6 in., cloth. $5.00.

This book is based on a series of semi-popular lectures given in the evening session of the University of Buffalo by the Assistant Professor of Physics. The book attempts to fill the double purpose of providing a unified picture of the subject which can be understood by the intelligent reader without technical training, and of giving the designer and maker of sets concrete information. The author has produced a good introductory book which explains the fundamental theory and the ways in which it is applied to the reception and amplification of signals.

Probleme der Elektro-Pathologie.

By Fritz Schwzyer. Zurich, Fachschriften-Verlag u. Buchdruckerei, 1926. 20 pp., 10 x 7 in., paper. Price not quoted.

This reprint from the Bulletin of the Swiss Society of Electricians contains a paper by a physician upon the treatment of sufferers from electrical shocks. The author attempts to interpret the thought of the medical profession to the electrical industry and at the same time to bring to the attention of the latter the fundamentals of electrical engineering, in order to facilitate mutual understanding in the case of an accident. He gives a hypothesis concerning the action of alternating currents upon the living cell.

Proceedings of the Optical Convention, 1926. London.

Lond., Optical Convention, 1926. 2 v., illus., diagrs., port., tables, 10 x 8 in., cloth. 3 lbs. (2 v.).

The scientific proceedings of the Optical Convention held in London last spring are given in these two volumes. The publication contains many papers of importance on the manufacture of optical glass and optical elements, the design of instruments, on color, photometry and illumination, astronomy, geodesy, photography and other optical subjects. Nearly one hundred papers are included. They cover a wide range and constitute a valuable record of progress in optical science and instrument design since the previous convention in 1912.

RADIOTECHNIK, v. 3; Die Empfanger.

By Hermann Saacke, Ber. u. Lpz., Walter de Gruyter & Co., 1926. 115 pp., illus., diagrs., 6 x 4 in., cloth. 1,50 r. m.

The third volume of this concise little introductory textbook is devoted to receiving apparatus, both telephonic and telegraphic. An unusually clear presentation of the theoretical principles is given, and the usual circuits are explained.

STEAM-ENGINE AND OTHER HEAT-ENGINES.

By Sir J. Alfred Ewing. 4th edition. Cambridge, University Press; N. Y., Macmillan Co., 1926. 662 pp., illus., diagrs., tables, 9 x 6 in., cloth. $8.50.

The fourth edition of this well-known treatise has been revised throughout and many additions have been made to care for advances since the appearance of the preceding edition, in 1910. The chapters on turbines, boilers and internal-combustion engines have been largely rewritten and the data on the properties of steam have been revised to agree with those obtained by Callendar. The discussion of thermodynamic principles has been rewritten. This edition, like its predecessors, is intended to present the mechanical and thermodynamical aspects of the subject with sufficient fullness for the ordinary needs of university students.

STORY OF THE ROTOR.

By Anton Flettner. N. Y., F. O. Willhofft, 68 Beaver St., 1926. 110 pp., illus., port., diagrs., 9 x 6 in., cloth. $2.00.

Follows the evolution of the inventions of the author from their inception to their practical realization. Brings out in interesting fashion the way in which each invention has led to the next, and traces the sequence from the current-actuated airplane rudder to the ship rudder and from this to the rotor, with its applications to sailing ships and windmills. The style is narrative and not technical, the book being intended to acquaint the general public with the inventions.

THEORY OF ELECTRICITY.

By G. H. Livens. 2d edition. Cambridge, University Press; N. Y., Macmillan Co., 1926. 427 pp., 9 x 6 in., cloth. $5.50.

Professor Livens has set for himself the task of presenting "a complete account of the purely theoretical side of the subject in the only form in which it appears to be satisfactory from the point of view both of mathematical consistency and of physical completeness." The work covers the older form of theory, based on the original framework of Faraday and Maxwell and developed by Larmor and Lorentz. Certain aspects of electromagnetic theory which are often rather neglected, such as the mechanical relations of polarized media, are treated with fullness.

THREE LECTURES ON ATOMIC PHYSICS.

By Arnold Sommerfeld. N. Y., E. P. Dutton & Co., 1926. 70 pp., 8 x 5 in., cloth. $1.00.

Contents: General remarks on atomic physics, in particular on the spectra of hydrogen and helium.—The general system of the complex terms.—Chemical bonds and crystal structures.

These lectures, first delivered at London University, are interesting as a statement of Dr. Sommerfeld's opinions on current problems of atomic physics.

WATER POWER ENGINEERING.

By H. K. Barrows. N. Y., McGraw-Hill Book Co., 1927. 734 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.00.

Intended primarily as a text for use in courses given at the Massachusetts Institute of Technology, this book discusses the applications of hydrology, hydraulics and mechanics involved in the design of water-power plants and the electric transmission of power. Starting with a review of the distribution of water power and its use throughout the world, the book discusses hydrology, the study of stream-flow data, turbines, plant arrangement, dams, canals, power-house equipment, regulation, transmission, costs, reports, etc. Much practical information is brought together in convenient form.

WATERWORKS HANDBOOK.

By Alfred D. Flinn, Robert S. Weston and Clinton L. Bogert. 3rd edition. N. Y., McGraw-Hill Book Co., 1927. 871 pp., illus., diagrs., tables. 9 x 6 in., cloth. $7.00.

The third edition of this standard work of reference has been carefully and thoroughly revised and in part rewritten. The authors have also attempted in this edition to make the book serviceable to engineers and contractors interested in irrigation, power, railroads and highways, although it still is intended primarily for waterworks men. The bibliographic references are unusually extensive.

DIE WIRTSCHAFTLICHE REGELUNG VON DREHSTROMMOTOREN DURCH DREHSTROMGLEICHSTROM-KASKADEN.

By H. Zabransky. Berlin, Julius Springer, 1927. 112 pp., illus., diagrs., tables, 10 x 7 in., paper. 9.-r. m.

An examination of the theory, properties and fields of usefulness of the cascade method for regulating the speed of asynchronous motors, based upon practical results extending over several years. The volume opens with a brief history of the method. The two principal systems, those of Kraemer and Scherbius, are then discussed in detail, attention being paid to the wiring, method of operation, design, regulation, braking, etc. The economics of these systems are discussed in section three, and the final section treats briefly of construction.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
53 West Jackson Blv'de., Room 1736, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

(See also page 42, Advertising Section.)

RESEARCH GRADUATE, ASSISTANT IN ENGINEERING EXPERIMENT STATION, devoting one-half time to engineering, balance to graduate study. Position affords excellent preparation for teaching, research and general engineering practise. Salary $600 a year and freedom from fees. Apply by letter. Location, Middle-west. X-1797-C.

ENGINEER, with some technical knowledge in laying out and developing outdoor switching equipment. Location, Pennsylvania. R-8601-C.

ENGINEERING GRADUATE, who has had experience with rectifier and audio frequency circuits, either in radio or telephone work. For radio circuit work in connection with A and B battery eliminators. Must be capable of taking

charge of a well equipped laboratory employing a group of technical assistants. Opportunity. Salary $200-250 a month. Apply by letter, giving full details. Location, Massachusetts. X-1816-C.

ELECTRICAL OR MECHANICAL ENGINEER, young, college graduate, who has latent supervisory ability and who has determination enough to work hard for ultimate achievement. Apply by letter, with full particulars. Location, Chicago. X-1776-C.

MECHANICAL OR ELECTRICAL ENGINEERS, GRADUATE OR MEN WITH EQUIVALENT TRAINING. Work requires men who not only understand ways and means of improving tools, equipment and manufacturing methods but who also have the initiative and inventive ability actually to devise and carry out such improvements. Should have at least 3 years' experience in the manufacturing field. Apply by letter, giving education, age, experience and salary desired. Headquarters, Chicago. X-1777-C.

ELECTRICAL OR MECHANICAL ENGINEER, for electrical standards work. Should be technical graduate with several years' practical experience in electrical design and layout of automatic switch gears and associated plant equipment. Experience in motor testing desirable. Work involves standardization of electrical motor and control systems and distribution methods. Apply by letter. Location, Chicago. X-1882-C.

PROFESSOR AND ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING for rapidly growing school of engineering. Opportunity for men of initiative and thorough training. Salaries for these positions will depend to a large extent on the qualifications of the applicant. Appointments for Fall, 1927. Apply by letter giving full particulars of education and experience. Location, Southwest, X-1890-C-S.

INSTRUCTOR in electrical engineering, for scholastic year. Salary $1800 a year. Apply by letter stating education, experience and age and enclose photograph. Location, South. X-1568-C.

MEN AVAILABLE

SECRETARY, TREASURER, OR OFFICE MANAGER, with over twenty-five years' experience in engineering and construction of public utilities. Accountant and systematizer. Energetic and reliable. Available immediately, any location. Position with established business desired rather than high salary. Unquestionable references from present employer and others. Excellent reasons for making change. C-2430.

ENGINEER, 27, single, desires position with consulting, contracting or manufacturing concern. Well trained chiefly in E. E., also in mechanical and civil engineering. Three years' experience before graduation and two years as graduate engineer with a public utility. Capable to produce good results. Speaks foreign languages. Available on two weeks' notice. Location immaterial. C-696.

ELECTRICAL ENGINEER, graduate, eleven years' general experience in engineering, consisting of the students' course offered by the G. E. Company, service engineer, inspector engineering material, design small power plants, including manual and automatic control equipment, writing specifications, as well as correspondence. Desires position as power or service engineer. Location preferred, Metropolitan District. B-924.

ELECTRICAL ENGINEER, with executive ability, competent in electrical and mechanical design and manufacture of electrical machines and apparatus; familiar with layout and operation of power and substations; able to systematically carry on scientific and practical research work in electrical, mechanical and physical problems, with very good experience in automotive electric traction. Speaks German and French. Wishes to make new connection. C-693.

EXECUTIVE CONNECTION desired by electrical engineer, preferably in the South. During past several years organized and am still directing nation wide engineering service. Technical graduate 1907. Eight years Westinghouse service. Two years heavy electrical railway work. Steam railroad experience, telegraphing and some business experience. B-122.

ELECTRICAL ENGINEER, with broad engineering, manufacturing, construction and public utility experience, desires executive position with manufacturer, public utility or exporters of electrical machinery and equipment. Location desired East. Available on short notice. B-9176.

SEMI-TECHNICAL MAN, with some college training, several years' experience in the operation, maintenance and repair of electrical equipment, desires position in the New England states. B-8150.

ENGINEER, electrical, 26, single, M. S., three years with G. E. Company; one year test, one year radio development, one year high-voltage development. Now with outstanding radio organization. Available March. C-211.

COMMERCIAL ENGINEER, graduate 1908, thoroughly experienced in power sales for large industrial operations, invites correspondence with holding company who require executive to organize actively department for negotiations of larger power contracts and to build up power load. A successful record and highest type of reference as to character, ability of accomplishment and personality offered. B-4221.

JUNIOR ELECTRICAL ENGINEER, wishes to make connection with an electrical firm as assistant to test engineer. Available in one week. Location in New York City. C-2451.

POWER AND MAINTENANCE MAN, with experience in industrial plants, manufacturers and power house construction and maintenance, desires position. Available on two weeks' notice. Location desired, New York City. C-2482.

POSITION DESIRED, by recent E. E. graduate, with a small consulting firm in New York City. Has design and construction experience. Married. C-1514.

GRADUATE ELECTRICAL ENGINEER of Bliss Electrical School, age 25, single, desires position in sales or junior engineering. Experience in machine shop, inspection of automatic telephone exchange installation, various meter department work coupled with meter engineering of public utility and sales. Available at once. Location, East or Pacific Coast. C-1570.

SUPERINTENDENT OF ELECTRICAL CONSTRUCTION, 34, married, thoroughly competent to take complete charge of large installations. Six years' actual experience on commercial buildings, city schools, power plants and signal stations. Would also consider plant maintenance. Master License. Available immediately. Location preferred, New York City. B-9638.

INSPECTION ENGINEER, 36, married, long experience representing purchaser at manufacturer's plant on inspection of all kinds of electrical equipment. Recently completed inspection of Muscle Shoals electrical equipment and tested installation. Cornell M. E. Westinghouse test course. Location immaterial. B-3625.

PROFESSOR OF ELECTRICAL ENGINEERING in a university of high standing, will consider a change of institutions if administrative responsibility, larger opportunity and income are available. Sound practical experience as well as excellent liberal and technical training. Member of honorary and professional societies. B-7925.

TECHNICAL GRADUATE, mechanical-electrical engineer, G. E. test, twenty years' experience union and non-union labor in States, Alaska and Mexico. Familiar with best practice coal and metal mining and milling; all phases, mechanical-electrical operation and repair. Mining or industrial position preferred. Will go anywhere. At present employed. B-8872.

ENGINEERING EXECUTIVE, technical graduate, fifteen years' experience; ten years electric utility manager. Can make a property pay and build sound public policy; rate making, power sales. Desires position with electric utility or sales work with engineering concern. Age 37, married. B-6090.

ELECTRICAL ENGINEER, 28 Englishman, twelve months in United States, desires opportunity where the following training and experience could be utilized. Eleven years technical and practical electrical engineering covering iron and steel works electrical application, installation and maintenance, central stations, and plant erection for large manufacturing company in England. Oil fields electrification India, and public utilities in United States. Extensively traveled. Would undertake foreign representation or sales, or erection, or inspection of electrical plant and machinery. C-625.

ELECTRICAL ENGINEER, 29, married, six and one-half years' experience in metering, plant and apparatus testing, power factor correction and trouble investigation, desires position. Available in two weeks. Location preferred, Eastern States. B-6546.

ENGINEER WANTS WORK, East of Illinois or on Pacific Coast at location having gas, water and electric service. M. E., E. E. (Cornell) Paper mill and other industrial experience. Practical steam and power production work. Industrial power sales engineer. Executive experience as district engineer large electrical manufacturer, also erecting engineer. References. B-6764.

ELECTRICAL ENGINEER, age 36, Lehigh University graduate. Now employed invites correspondence with prospective employer desiring services of competent engineer and executive fully experienced in power and mining industry. Will consider any location providing future is attractive with opportunity leading eventually into management. Clear record. Energetic and aggressive worker for best interest of employer. Available in one month. B-4905.

ENGINEER-ACCOUNTANT, graduated in Electrical Engineering; trained in a large operating company; experienced in supervision and management; 10 years with a Public Service Commission, mostly as departmental head; capable of taking charge of rate, valuation or accounting department, or managerial position; can prepare and present any utility case before a court or commission. C-2569.

ELECTRICAL ENGINEER, 31, married, BSE 1921, and E. E. 1922 from University of Minnesota. 1 year Westinghouse graduate engineering school, 13 years' experience in pole line construction, conduit wiring, station operation, design of substations and distribution systems. and now engineer for division of large power company. Desires change of position. Available on one month's notice. C-2563.

GRADUATE ELECTRICAL ENGINEER, age 30, married, desires position with firm or public utility. Three years' experience with public utility as electrician, switchboard operator, and load dispatcher. Available at once. C-2564.

ELECTRICAL ENGINEER, 35, technical graduate. G. E. Test graduate. 5 years' engineering experience with a large manufacturing company, in underground high voltage cable, general switchboard, railway and automatic sub-station work, desires position with a consulting, public utility, or construction company. C-2565.

ENGINEER, age 27, married. 1925 graduate from well known electrical school, desires position as radio interference engineer, with possibility of advancement. Has 10 years' commercial and amateur radio experience, specializing on radio interference. Also has experience in distribution, operation, and maintenance work. Location preferred, Pacific Coast. Available 30 days' notice. C-2568.

ELECTRICAL ENGINEER, ten years on high and low tension utility and industrial installations, as designing engineer, chief draftsman, superintendent of construction, purchasing engineer, and

specifications writer. Location near Philadelphia preferred, but will go anywhere. C-2570.

ELECTRICAL ENGINEER, 31, married, desires responsible position with engineering concern or public utility. Three years transmission and distribution, two years construction, one year station, and one year industrial experience. At present in responsible position with large Eastern Utility. Available one month. Location, New York City, or within 100 mile radius. C-658.

ENGINEER, expert at utilization of spare electric power for steam generation (electric boilers), furnaces and industrial purposes generally, wishes permanent or temporary connection. Is also well trained in power house and substation design, construction and equipment, and experienced in inventory, pricing, valuation, and general company work. B-8863.

GRADUATE ELECTRICAL ENGINEER desires to use his seven years' high tension construction, testing, and operating experience as a basis for sales engineering. Age, 30, married. Middle-West preferred. B-6010.

TEACHER IN ELECTRICAL ENGINEERING, 31, single, four years' teaching experience in an Eastern University of high standing. Holds M. E. E. and Ph. D. degrees from that University. Desires position as professor in a technical school or university having opportunities for research. Available, June, 1927. B-4977.

INDUSTRIAL ENGINEER, technical mechanical electrical engineer, with ten years' experience in factory operation, organization, and management, desires position in South America or the Orient. At present, production manager of a factory of fifteen hundred. Has specialized in re-organization, made a close study of human nature, and its power of production. C-1070.

PROFESSOR OF ELECTRICAL ENGINEERING, desires change, holds degrees from two large American universities. Has twice risen to be head of E. E. departments in State College. Fine administrator and teacher. Age 41, married. Protestant, member of A. I. E. E. and S. P. E. E. Correspondence invited. C-2155.

ELECTRICAL AND ILLUMINATING ENGINEER, licensed New York State Professional Engineer. Member A. I. E. E., age 35, fifteen years' experience construction and design, substations, power-houses, etc., and on valuation and appraisal for utilities and the Interstate Commerce Commission. Executive ability, good personality. Opening in either sales engineering or electrical engineering. B-9079.

ELECTRICAL MECHANICAL DRAFTSMAN, married, technical graduate, 9 years' field and office experience on power house construction and machinery. Available immediately. B-7666.

PUBLIC UTILITY ENGINEER AND EXECUTIVE. Has constructed, operated, managed, inventoried and valued electric properties, and constructed and valued gas properties. Also reported upon, purchased and sold waterpowers. Familiar with public utility accounting. A-2280.

GRADUATE ELECTRICAL ENGINEER, 26, married, three years' experience with a light and power company; one year as student engineer, and two years as design draftsman. Desires change of position and location. Middlewest preferred. Available on thirty days' notice. C-2581.

ENGINEER, 29, single, thirteen years' experience in design, construction and operation of complete transmission and distribution systems, and electrical layout of power plants; testing of all types meters; local managing; electrical contracting. Desires position in operating or engineering departments of power company. Location preferred, California. C-2566-72-C-1.

PRODUCTION MANAGER, experienced in the manufacture of electrical and mechanical apparatus. Familiar with modern methods of scheduling, stocking, cost keeping, wage payments, machine practise, etc. Has successfully carried responsibility and able to diplomatically mould a factory into an economical, efficient and harmonious organization. B-7331.

AGENTS' REPRESENTATIVES

AGENCIES DESIRED for all Canada or Province of Quebec of electrical apparatus, instruments and accessory equipment, also associated mechanical equipment for mining, industrial and central station fields. Directing head of company has had long experience as sales manager and sales engineer as well as sound designing and practical training. C-2498.

PHILADELPHIA FIRM of five years standing would be glad to hear of any established concerns desiring representation in the Philadelphia territory in boiler and furnace specialty lines. A-4174.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED FEBRUARY 10, 1927

AGNEW, EDWARD JAMES, Engineering Assistant, Western Union Tel. Co., 195 Broadway, New York; res., Brooklyn, N. Y.

*AHLBERG, ALVIN E., Valuation Engineer, General Appraisal Co., 408 Marion St., Seattle, Wash.

AHLQUIST, ROBERT WILHELM, Instructor, University of Pittsburgh, 207 Thaw Hall, Pittsburgh; res., Wilkinsburg, Pa.

AHRENS, JUSTIN H., The Hart & Hegeman Mfg. Co., 342 Capitol Ave., Hartford, Conn.

ALBERT, ARTHUR LEMUEL, Instructor, Electrical Engineering Dept., Oregon Agricultural College, Corvallis, Ore.

*ALBRECHT, ERNEST GEORGE, Transmission Inspector, Tri-State Tel. & Tel. Co., 8th & Cedar Sts., St. Paul, Minn.

*ALLEN, W. MORGAN, Electrical Draftsman, Washington Water Power Co., 825 Trent, Spokane, Wash.

ALMGREN, EARL WILLIAM, Lumbering, Almgren Bros. & Lindberg, Tiger, Colo.

*AMBROSE, JOSEPH S., General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Clairton, Pa.

AMRHEIN, GEORGE HAROLD, Test Equipment Inspector, New York Telephone Co., 104 West St., New York; res., Hollis, N. Y.

ANDRES, JOHN FREDERICK, Chief Tester, So. California Telephone Co., 1525 W. Vernon Ave., Los Angeles, Calif.

*ANFANG, EDWARD LOUIS, Draftsman, Elec. Dept., Allis-Chalmers Mfg. Co., West Allis; res., Milwaukee, Wis.

ASHLEY, JERRY MORRIS, Engineering Dept., Youngstown Sheet & Tube Co., Youngstown, Ohio.

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BAKER, HAMMOND D., Sales Engineer, 602 Ford Bldg., Detroit, Mich.

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BALFOUR, MELVILLE WILBERT, Assistant Engineer, Station Design, Public Service Co. of No. Illinois, 72 W. Adams St., Chicago; res., Oak Park, Ill.

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*HOOPER, WILLIAM EDWARD, Junior Engineer, Alabama Power Co., Birmingham, Ala.
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*LUSIGNAN, JOSEPH THEODORE, Graduate Student, Stanford University, Calif.
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MASTER, WARREN, Laboratory Assistant, Brooklyn Edison Co., Pearl & Johnson Sts., Brooklyn, N. Y.
*McCARTHY, ALBERT JOSEPH, Test Engineer, Experimental Dept., Otis Elevator Co., Wells Ave., Yonkers, N. Y.
McCOY, JOHN C., Cost Engineer, Construction Dept., Pacific Gas & Electric Co., 245 Market St., San Francisco, Calif.
McIVOR, JAMES GERALD, Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*McKIBBEN, WAYNE E., Student Engineer, General Electric Co., 1 River Road, Schenectady, N. Y.
*McKINLEY, REID, Engineer, Union Switch & Signal Co., Swissvale, Pa.
McLEAN, LLOYD A., Assistant Substation Foreman, Ohio Power Co., 720 2nd St., S. E., Canton, Ohio.
*McMILLAN, JAMES, Engineering Student, Canadian Westinghouse Co., 163 Sanford Ave., N., Hamilton, Ont., Can.
MEIHOFF, AMIEL DIETRICH, Northwestern Electric Co., Portland, Ore.
MENDEZOFF, LOUIS MICHAEL, Substation Operator, Cleveland Electric Illuminating Co., 75 Public Square, Cleveland, Ohio.
*MILLE, RALPH RAYMOND, Engineer, Small Motor Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
MILNE, JOHN ALEXANDER, Engineer in charge, Westport Coal Companies, Millerton Mine, Granity, Westport, N. Z.
*MOLLMAN, L. A., Junior Engineer, Union Electric Light & Power Co., 315 N. 12th Blvd., St. Louis, Mo.
MONAGHAN, WILLIAM JOSEPH, Assistant Operator, Distributing Stations, New York Edison Co., 327 Rider Ave., New York, N. Y.
MOODY, LAWRENCE E., Associate, Isaac Hathaway Francis, Consulting Engineer, 1520 Locust St., Philadelphia, Pa.
MORAN, JOHN V., Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*MORLEY, FRANK WALTON, Electrical Tester, B. F. Sturtevant Co., Damon St., Hyde Park, Mass.
*MORTON, RALPH MACKENZIE, Junior Assistant Engineer, Switchboard Dept., Canadian General Electric Co., Peterboro, Ont., Can.
MOTT, EVERETT VICTOR, Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York, N. Y.
*NELSON, CLARENCE HERMAN, Assistant Engineer, Public Service Co. of No. Illinois, 72 W. Adams St., Chicago, Ill.
NESMITH, JAMES, 2nd, Foreman Electrician, Public Service Electric & Gas Co., Kearny Power Station, Kearny, N. J.
OCK, WESLEY ANDREW, Telephone Equipment, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., Maplewood, N. J.
OLMSTEAD, CHAUNCEY LISLE, Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York, N. Y.
OSGERBY, FENTON L., Engineer, Detroit Edison Co., 2000 Second Ave., Detroit, Mich.
O'SULLIVAN, LOUIS, Civil Engineer, Montreal Light, Heat & Power Consolidated, 83 Craig St., Montreal, Que., Can.
OWENS, EMMETT LEE, Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York; res., Brooklyn, N. Y.
*PAPST, HUGH W., Switchboard Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
*PATTEN, EMERSON KEILHOLTZ, Engineering Assistant, The Chesapeake & Potomac Telephone Co., 108 E. Lexington St., Baltimore, Md.
PATTON, JAMES HUNTINGTON, Sales Engineer, Sangamo Electric Co., Springfield, Ill.
PAULI, HENRY F., Assistant, Research Laboratory, Thomas A. Edison, West Orange, N. J.
PECK, GORDON V., Sales Manager, Condenser Corporation of America, 25 Waverly Place, New York, N. Y.
*PECK, WILLIAM GREER, Student, School of Engineering of Milwaukee; res., 531 Cass St., Milwaukee, Wis.
PENNOYER, DOUGLAS HUNTINGTON, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
PEPIN, HARRY E., Electrical Draftsman, Public Service Power & Light Co., 605 Electric Bldg., Seattle, Wash.
PETERS, HARRY LOUIS, Transmission Engineer, Bell Telephone Co. of Pa., 1835 Arch St., Philadelphia, Pa.
*PETRUSKA, JOHN J., Student Engineer, Philadelphia Electric Co., Philadelphia, Pa.
*PIEPHO, EDWARD ERNEST, Operating Dept., Detroit Edison Co., Detroit, Mich.
PIPER, REUBEN WILLIAM, District Manager, Pittsburgh Transformer Co., 733 Healey Bldg., Atlanta, Ga.
*PRUDHAM, WILLIAM MERRILL, Switchboard Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
*RANDHAWA, SAUDAGAR SINGH, Student Engineer, General Electric Co., Lynn, Mass.
RASKHODOFF, NICHOLAS M., Laboratory Assistant, American Bosch Magneto Corp., Springfield, Mass.
RICH, THEODORE ALFRED, Standardizing Laboratory, General Electric Co., West Lynn; res., East Lynn, Mass.
RIGGS, GEORGE, Systems Development Engg. Dept., Bell Telephone Laboratories, 463 West St., New York, N. Y.
*RITTER, E. W., Electrical Engineer, Cleveland Vacuum Tube Works No. 30, General Electric Co., Nela Park, Cleveland, Ohio.
ROBB, WILLARD FREDERICK, Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., Bloomfield, N. J.
*ROBBINS, CHARLES LALOGE, Inspector, Electrical Testing Laboratories, 540 E. 80th St., New York, N. Y.
ROBERTSON, CHARLIE MONROE, Supt., Dist. Maintenance Dept., Georgia Railway & Power Co., 211 Decatur St., Atlanta, Ga.
ROBERTSON, DOUGLAS, District Contract Engineer, Canadian General Electric Co., Ltd., 1065 Pender St., W., Vancouver, B. C., Can.
ROBERTSON, L. M., In Charge Transmission Engg. Dept., Public Service Co. of Colorado, Denver, Colo.
ROBINSON, ALLAN McLEOD, Equipment Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

ROBINSON, CORNELIUS P., Synchronous Engineer, Ideal Electric & Mfg. Co., Mansfield, Ohio.

RODILES, MANUEL M. G., Supt., Hydro-Electric Plant, Compania Cubana Electricidad, Guantanamo, Cuba.

*RODWIN, GEORGE, Engineer, Radio Corporation of America, 70 Van Cortlandt Park, South, New York, N. Y.

ROZIER, HAROLD FRANCIS, Assistant Electrical Engineer, F. R. Weller, 601 Mills Bldg., Washington, D. C.

*SCHECK, ALAN HALE, Engineer on Automatic Control, Duquesne Light Co., Duquesne Bldg., Pittsburgh, Pa.

SCHERB, ETIENNE, Draftsman, General Electric Co., 6801 Elmwood Ave., West Philadelphia; res., Philadelphia, Pa.

*SCHOFIELD, JACOB E., Shop Electrician, Southern Colorado Power Co., Victor, Colo.

*SCHRAMM, FREDERIC B., Designing Engineer, Induction Motor Engg. Dept., General Electric Co., Schenectady, N. Y.

SCOFIELD, ROBERT W., Electrical Engineer, New York & Queens Electric Light & Power Co., Flushing; for mail, Brooklyn, N. Y.

*SEECAMP, JOHN FLEXMAN, Electric Meterman, Puget Sound Power & Light Co., 7th & Olive Sts., Seattle, Wash.

SHAW, ROBERT MacKENZIE, 1st Lieut., Signal Corps, U. S. A., Headquarters, Camp Lewis, Wash.

SHIMIDZU, KICHIZO, Electrical Engineer, Sumitomo Elec. & Wire Cable Works, Okijimaninamino-cho, Konohanaku, Osaka, Japan.

*SHRIBER, HOWARD, Metering Inspector, Deschutes Power & Light Co., Bend, Ore.

SIEGEL, MILLARD CHESTER, Survey Tracer, Brooklyn Edison Co., Inc., 360 Pearl St., Brooklyn; res., Woodhaven, N. Y.

SIGNOR, CHAUNCY B., Engineer, Cia. Cubana de Electricidad, Inc., Santiago, Cuba.

SIMOKAITIS, BRUNO, Chief Electrician, Simonds Saw & Steel Co., 1624 S. Western Ave., Chicago, Ill.

SKLAR, SAMUEL BARTON, Chemical, Mechanical and Electrical Inventor, Hotel Statler, Detroit, Mich.

SNYDER, EDWIN H., Engineer, Electric Dept. Public Service Electric & Gas Co., 80 Park Place, Newark, N. J.

SORTÈBERG, JOHANNUS, 182 Cumberland St., Brooklyn, N. Y.

SPENCER, THOMAS ANCRUM, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York; res., Brooklyn, N. Y.

*SPERR, WALTER H., Cadet Engineer, Brooklyn Edison Co., Inc., 380 Pearl St., Brooklyn, N. Y.

SPIETH, JOSEPH THEODORE, Assistant to Superintendent of Power, Western District, Florida Power & Light Co , Lakeland, Fla.

*STRANDBERG, HERBERT VICTOR, Computer, City of Seattle Engineering Dept., Seattle, Wash.

*STRIEDER, HENRY PHILIP, Cadet Engineer, Electrical Dept., Laclede Gas Light Co., 1017 Olive Street, St. Louis, Mo.

SUMNER, JOHN R., Assistant Engineer, Electric Dist. & Constr. Dept., Rochester Gas & Electric Corp., Rochester, N. Y.

*SUTHERLAND, DANIEL JAMES, Draftsman, Switchboard Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

*SWALES, JAMES K., Assistant Engineer, United Power & Light Corp., 117 N. Main Street, Hutchinson, Kansas.

SWECKER, O. E., Telephone Engineer, Chesapeake & Potomac Tel. Co., 725 13th St., Washington, D. C.

SWEINHART, EARLE FREDERICK, Chief Electrician, Pacific Door & Sash Co., 3450 San Fernando Road, Los Angeles, Calif.

*TAMES, JOHN ALEX, Engineering Student, Canadian Westinghouse Co., Ltd., 163 Sanford Ave., N., Hamilton, Ont., Can.

*TAYLOR, WILLIAM FREDERICK, Graduate Student Engineer, Allis-Chalmers Mfg. Co., West Allis, Wis.

TEARE, NORMAN ALLAN, Engineer & Draughtsman, Engineering Dept., Montreal Light, Heat & Power, Cons., Power Bldg., Montreal, P. Q., Can.

TERRANCE, EMMETT HOWARD, Electrical Engineer, The Detroit Edison Co., 2000 Second Ave., Detroit, Mich.

TERRY, GEORGE SKELTON, Electrical Engineer, Stone & Webster, 147 Milk St., Boston, Mass.

*TERRY, IRA ANDERSON, Student Test Course, General Electric Co., Schenectady, N. Y.

THOMAS, ALFRED JOSEPH, Electrical Engineer, L. J. Healing & Co., Ltd., Yusen Bldg., Tokyo, Japan.

THOMAS, CLYDE U., Cable Tester, Underground Division, Duquesne Light Co., Pittsburgh, Pa.

THOMAS, ROSS PHILLIP, Assistant Professor of Physics & Engineering Drawing, Wittenberg College, Springfield, Ohio.

THORNTON, HENRY PENDLETON, Division Engineer, Postal Telegraph-Cable Co., Atlanta, Ga.

*TUNG, CHI-TAI, Testing Dept., General Electric Co.; res., 8 Union St., Schenectady, N. Y.

*TURNER, ELMER AUSTIN, Test Engineer, General Electric Co., Schenectady, N. Y.

UNDERWOOD, JOEL CURRY, Draftsman, Georgia Railway & Power Co., 1008 Glenn Bldg., Atlanta, Ga.

VAN BRUNT, LeROY CHADWICK, Assistant to Foreman, Westinghouse Elec. & Mfg. Co., East Springfield; res., Springfield, Mass.

*VENDLEY, CLARENCE ELIM, Draftsman, Southern California Edison Co., 306 W. 3rd St., Los Angeles, Calif.

VOELKER, FERDINAND, Jr., Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

WADDELL, JOHN JAMES, Town, Water Works & Chief Electrical Engineer, Borough of San Fernando, Trinidad, Town Engineer's Office, Town Hall, Trinidad, B. W. I.

WAHLGREN, RUSSELL SAMUEL, Assistant Engineer in charge Winding Dept., Gardner Electric Transformer Co., Emeryville, Calif.

*WALKER, T. S., In Charge of Mechanical & Electrical Activities, Red River Lumber Co., Westwood, Calif.

*WALL, WALTER I., Sales Engineer, Sunlike Illuminating Co., 475 Fifth Ave., New York; res., Brooklyn, N. Y.

WARNER, SEWARD ALGER, Engineering Assistant, Electrical Engineering Dept., Brooklyn Edison Co., 360 Pearl St., Brooklyn, N. Y.

WEAVER, GEORGE W., Circuit Design Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., Westwood, N. J.

*WELSH, WILLIAM JOSEPH, Statistician, Engineering Department, Puget Sound Power & Light Co., 1306 So. A. St., Tacoma, Wash.

WHAREN CHARLES GRIFFITH, Foreman of Repairmen, Bell Telephone Co. of Pennsylvania, 140-142 S. Washington St., Wilkes-Barre; res., Kingston, Pa.

WILLEVER, HARRY CAVANAUGH, Electrical Supervisor Edison Portland Cement Co., Stewartsville, N. J.

*WILLIAMS, LOYD THOMAS, Assistant Distribution Engineer, Southwestern Gas & Electric Co., 430 Travis St., Shreveport, La.

WILLIFORD, OSCAR H., Testing Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York; res., Brooklyn, N. Y.

*WILMOT, FRANCIS EUGENE, Junior Engineer, Duquesne Light Co., 435 6th Ave., Pittsburgh, Pa.

WITHROW, EDGAR LEWIS, Division Supervisor, Methods & Results, Installation Dept., Western Electric Co., Inc., 397 Hudson St., New York, N. Y.

WOLCOT, BYRON CONROD, Assistant Transmission Engineer, Kansas City Telephone Co., Telephone Bldg., 11th & Oak, Kansas City, Mo.

*WOLFE, KARL MORGAN, Assistant Cadet Engineer, Testing Dept., Monongahela West Penn Public Service Co., Rivesville; res., Kingwood, Preston Co., West Va.

*WOODMAN, CHARLES MERRILL, Transmission Engineer, Southwestern Bell Telephone Co., F. & M. Bank Bldg., Fort Worth; res., Dallas, Texas.

WOODROW, C. A., Central Station Engineer, General Electric Co., Schenectady, N. Y.

WOODRUFF, RALPH TERRY, Electrical Inspector, Hartford Steam Boiler Inspection & Insurance Co., Memphis, Tenn.

WOOLF, EDWARD LAWRENCE, Telephone Engineer, Western Electric Co., 268 W. 36th St., New York, N. Y.

YERGER, LLOYD K., Meterman, Buffalo General Electric Co., 960 Front Ave., Buffalo, N. Y.

ZOLLER, JOHN, Equipment Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

Total 280.

*Formerly enrolled students.

ASSOCIATES RE-ELECTED FEBRUARY 10, 1927

BRANTLY, EDGAR CLAYTON, Superintendent, Light & Power, City of Danville Electric Dept., Danville, Va.

CRANDALL, H. N., Electrical Contractor Dealer, The Dalles, Ore.

LINDSLEY, FLOYD M., Test Methods Engineer, Western Electric Co., 149 Fulton St., New York, N. Y.

ONARHEIM, JAMES I., Electrical Engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

MEMBERS ELECTED FEBRUARY 10, 1927

BENNION, HOWARD SHARP, Director of Engineering, National Electric Light Association, 37 W. 39th St., New York, N. Y.

BOCEK, THOMAS, Electrical Designer, J. G. White Engineering Corp., 43 Exchange Place, New York; res., Brooklyn, N. Y.

BRANTLEY, EDGAR POMEROY, Engineer, Georgia Railway & Power Co., 201 Glenn Bldg., Atlanta, Ga.

HULL, LEWIS MADISON, Director of Research, Radio Frequency Laboratories, Inc., Boonton, N. J.

MASON, HOBART, Assistant Traffic Engineer Western Union Telegraph Co., 195 Broadway New York, N. Y.; res., Westfield, N. J.

MILLER, JOHN ZOLLINGER, Secretary & General Manager, Mutual Telephone Co., 20-26 E. 10th St., Erie, Pa.

RENDELL, EDWARD FRANK, The Operating Electrical Engineer, The Victoria Falls & Transvaal Power Co. Ltd., Cleveland, Transvaal, So. Africa.

TEEVAN, GEORGE BERNARD, Assistant, Meter Engineer, Brooklyn Edison Co., Inc., 14 Rockwell Place, Brooklyn, N. Y.

WORDEN, BEVERLY L., President, The Cutler-Hammer Mfg. Co., 12th St. & St. Paul Ave., Milwaukee, Wis.

TRANSFERRED TO GRADE OF FELLOW FEBRUARY 10, 1927

SUTHERLAND, GEORGE, Electrical Engineer, Duquesne Light Co., Pittsburgh, Pa.

TRANSFERRED TO GRADE OF MEMBER FEBRUARY 10, 1927

BALLARD, HAROLD L., Supervisor of Instruction, Michigan Bell Tel. Co., Detroit, Mich.

BESSESEN, B. B., Instructor in Electrical Engineering, Oregon Agricultural College, Corvallis, Ore.
COOVER, WILLIAM E., Electrical Engineering Dept., Brooklyn Edison Co., Brooklyn, N. Y.
CRAFT, FRANCIS M., Chief Engineer, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
CREECY, C. E., Telephone Engineer, Chesapeake & Potomac Tel. Co., Washington, D. C.
CRUICKSHANK, CHARLES B., Asst. Cable Engineer, Interborough Rapid Transit Co., New York, N. Y.
GRAFF, JOHN T., Plant Results Supervisor, Chesapeake & Potomac Tel. Co., Washington, D. C.
HEBERT, JOSEPH A., Division Plant Engineer, Southern Bell Tel. Co., Charlotte, N. C.
HIGGINS, N. B., Asst. Chief Engineer, Penn. Water & Power Co., Baltimore, Md.
KNISKERN, FLOYD B., Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
LAFORE, J. A., Secretary and General Manager, John Lang Paper Co., Philadelphia, Pa.
LOYE, DONALD P., Telephone Engineer, American Tel. & Tel. Co., Philadelphia, Pa.
McCLURE, MILTON B., Engineer, Georgia Railway & Power Co., Atlanta, Ga.
PORTER, HARRY L., District Manager, Verne W. Shear & Co., Cleveland, Ohio.
SHIRLEY, ERNEST R., Asst. Switchboard Engineer, Canadian General Electric Co. Ltd., Peterboro, Ont.
TRABERT, ARCHIE W., Electrical Engineer, Industrial Electric Service Co., Aberdeen, Wash.
VAILE, HORACE S., Industrial Marketing Counselor, McGraw Hill Publishing Co., New York, N. Y.
VARIAN, CLARENCE E., Electrical Engineer, Spicer Mfg. Corp., South Plainfield, N. J.
WACKER, HERMAN, Telephone Engineer, Chesapeake & Potomac Tel. Co., Washington, D. C.
WISE, LYLE D., San Francisco, Calif.
ZIEGLER, EDWARD F., Designing Engineer, Duquesne Light Co., Pittsburgh, Pa.
KNOWLES, EVERETT H., Assistant Chief, Operation of Substations, Chile Exploration Co., Chuquicamata, Chile, S. A.
McGRATH, MAURICE K., Managing Director, Le Materiel Telephonique, Paris, France.
OSHIMA, HIROYOSHI, Director and Chief Engineer, Osaka Electric Lamp Co. Ltd., Osaka City, Japan.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held January 26, 1927, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

ELMEN, GUSTAF W., Member of Technical Staff, Bell Telephone Laboratories, Inc., New York, N. Y.
HEIDENREICH, ALLAN H., Consulting Engineer, Cleveland, Ohio.
MILLAN, WALTER H., Supt. of Substations, Union Electric Light & Power Co., St. Louis, Mo.
SCLATER, I. H., Section Head—Transformer Engg. Dept., General Electric Co., Pittsfield, Mass.

To Grade of Member

ATKINSON, ALBERT A., Professor of Physics and Electrical Engineering, Ohio University, Athens, Ohio.
BATES, GEORGE M., District Manager, American Brown Boveri Elec. Corp., Boston, Mass.
BEALS, W. B., Outside Plant Engineer, Chesapeake & Potomac Telephone Co., Washington, D. C.
BILLHEIMER, C. R., Assistant to Vice President, West Penn Power Co., Pittsburgh, Pa.
BLACKWEDEL, GEORGE H., Electrical Designer, 60 Wall Street, New York, N. Y.
BOLSTER, F. T., Electric Distribution Engineer, Syracuse Lighting Co., Inc., Syracuse, N. Y.
CHISHOLM, RAYMOND D., Sales Engineer, Westinghouse Elec. & Mfg. Co., New York, N. Y.
CLARKE, LIONEL C., Electrical Engineer, California Portland Cement Co., Colton, Calif.
COIT, NORMAN H., General Manager, Florida Public Service Co., Orlando, Florida.
COLE, HAROLD, Distribution Engineer, The Detroit Edison Co., Detroit, Michigan.
EBY, EUGENE D., Engineer, High Voltage Bushing Dept., General Electric Co., Pittsfield, Mass.
FAIRMAN, JAMES F., Assistant Electrical Engineer, Brooklyn Edison Co., Brooklyn, N. Y.
FISH, FREDERICK P., Lawyer, Fish, Richardson & Neave, Boston, Mass.
FORSTER, ROBERT, Engineer of Outside Plant, Up State, New York Telephone Co., Albany, N. Y.
FRY, AUGUST J., Assistant Engineer, Board of Supervising Engineers, Chicago Traction, Chicago, Ill.
GRANER, L. PETER, Electrical Engineer, Sprague Safety Control & Signal Corp., New York, N. Y.
HAZELTON, MERTON L., Assistant Electrical Engineer, Stone & Webster, Boston, Mass.
HOTCHKISS, FRED W., Sales Engineer, Electric Machinery Mfg. Co., Minneapolis, Minn.
JANSON, GEORGE W., Assistant to Apparatus Engineer, Western Union Telegraph Co., New York, N. Y.
KOHL, GEORGE HUTTON, Hydraulic Engineer, Spanish River Pulp & Paper Mills, Ltd., Saulte Ste. Marie, Ontario, Canada.
KREIDER, ROY H., Member of Technical Staff, Bell Telephone Laboratories, Inc., New York, N. Y.
LLOYD, WILLIAM E., Supt. of Transmission, Penna. Power & Light Co., Hazleton, Pa.
MALADY, J. A., Mechanical and Electrical Engineer, Hillman Coal & Coke Co., Pittsburgh, Pa.
McPHAIL, HARVEY F., Engineer, U. S. Bureau of Reclamation, Denver, Colo.
MICHELL, HUMPHREY G., Distribution Engineer, Cia Mexicana de Luz y Fuerza Motriz, S. A. Mexico, D. F. Mexico.
MILLER, FRANK H., District Engineer, Public Service Co., West Chicago, Ill.
MORGAN, DON D., Supt. Hydro Generation, Southern Calif. Edison Co., Los Angeles, Calif.
NULSEN, WILLIAM B., Radio Engg. Dept., General Electric Co., Schenectady, N. Y.
O'CONNELL, JAMES, Electrical Engineer, Virginia Public Service Co., Warrenton, Va.
PATES, ARTHUR J., Telephone Engineer, Chesapeake & Potomac Telephone Co., Washington, D. C.
PETERSON, ELMER G., Sales Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
RAMSEY, J. RAYMOND, Assistant to General Manager, Associated Gas & Electric Co., New York, N. Y.
SKINKER, MURRAY F., Assistant Director of Research, Brooklyn Edison Company, Brooklyn, N. Y.
STAVOLI, FRANCISCO J., Chief Engineer, Dept. of Radio and Electricity, Dept. of Education, Mexican Government, Mexico.
TAYLOR, DAVID B., General Supt. and Electrical Engineer, Troy Gas Company, Troy, N. Y.
THOMPSON, A. WARREN, Chief Engineer, Carolina Power & Light Co., Raleigh, N. C.
WRIGHT, FRANK T., Chief Electrical Engineer, Bombay, Caroda & Central India Railway, Bombay, India.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before March 31, 1927.

Ackermann, O., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Adams, A. W., Utah Power & Light Co., Wheelen, Utah
Ahrend, F. A., Staten Island Edison Corp., Livingston, Staten Island, N. Y.
Alexander, E. B., Lockport Light, Heat & Power Co., Lockport, N. Y.
Allen, N. L., (Member), American Zinc Co. of Tennessee, Mascot, Tenn.
(Application for re-election.)
Allison, S. W., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Altemus, F. B., Counties Gas & Electric Co., Norristown, Pa.
Anderson, E. K., Jr., Brooklyn Edison Co., Brooklyn, N. Y.
Anderson, F. C., Lehigh University, Bethlehem, Pa.
Antliff, J. C., Montreal Light, Heat & Power Co., Montreal, P. Q., Can.
Arnott, C., British Columbia Electric Railway Co., Vancouver, B. C., Can.
Ashley, R. L., Consolidated Gas, Elec. Lt. & Pr. Co., Baltimore, Md.
Avells, S. R., United Elec. Light & Power Co., New York, N. Y.
Barbor, V. H., Radio Corp. of America, Rocky Point, N. Y.
Baronigian, B., Contracting Co., 235 W. 28th St., New York, N. Y.
Berry, H. S., City of Los Angeles, Power Plant No. 2, Saugus, Calif.
Bjork, A. F., New York Telephone Co., Brooklyn, N. Y.
Bleecker, A. L., Philadelphia Electric Co., Philadelphia, Pa.
Bond, W. L., Jr., Brooklyn Edison Co., Brooklyn, N. Y.
Boveri, T., American Brown Boveri Electric Corp., Camden, N. J.
Bradfield, W. S., Western Electric Co., New York, N. Y.
Brock, M. B., Westchester Lighting Co., Mt. Vernon, N. Y.
Brookes, A. S., Public Service Electric & Gas Co. of N. J., Newark, N. J.
Brooks, B. H., (Member), Northern New York Tel. Corp., Plattsburgh, N. Y.
Brown, G. H., Philadelphia Electric Co., Philadelphia, Pa.
Brown, W. T., Philadelphia Electric Co., Philadelphia, Pa.
Burke, W. E., Western Union Telegraph Co., New York, N. Y.
Burlingham, K. R., Milwaukee Co. Institutions, Wauwatosa, Wis.
Bryan, W. J., Victor Talking Machine Co., Camden, N. J.
Caldwell, J. A., No. Indiana Public Service Co., Hammond, Ind.
Cannon, R. S., Pennsylvania Railroad, Altoona, Pa.
Chadbourne, D. K., (Member), Westinghouse Elec. Int. Co., New York, N. Y.
Chambers, W. G., Bell Telphone Co. of Pa., Philadelphia, Pa.
Chapman, C. S., Dixie Construction Co., Birmingham, Ala.
Cheatham, C. W., Alabama Power Co., Birmingham, Ala.
Clark, T. C., (Member), W. N. Matthews Corp., St. Louis, Mo.
Clayton, J. M., (Member), Institute of Radio Engineers, New York, N. Y.

Coffin, P. T., (Member), Aluminum Co. of America, New York, N. Y.
Cole, C. E., American Tel & Tel. Co., New York, N. Y.
Craig, A. B., Edison Electric Illuminating Co. of Boston, Boston, Mass.
Crever, F. E., General Electric Co., Schenectady, N. Y.
Cummins, W. M., Toledo Edison Co., Toledo, Ohio
Dally, T. B., Mutual Electric & Machine Co. of Detroit, Mich., New York, N. Y.
Dalzell, C. W., Union Switch & Signal Co., Swissvale, Pa.
Davison, W. J. M., Davison Engineering Co., Orizaba, Ver. Mex.
Dear, J. D., Bell Telephone Co., Philadelphia, Pa.
Della Corte, J. P., Sonora Phonograph Co., New York, N. Y.
Dennett, H. F., Michigan Railroad Co., Jackson, Mich.
DeRyder, H., New York Edison Co., New York, N. Y.
Douglas, W. A., Pacific Tel & Tel. Co., Seattle, Wash.
Duff, J. E., (Member), Sargent & Lundy, Chicago, Ill.
Durfee, B., Gilbert & Barker Mfg. Co., Springfield, Mass.
Eby, E. K., American Brown Boveri Corp., Camden, N. J.
Emery, L. D., Union Oil Co., Los Angeles, Calif.
Falkner, R. M., Brooklyn Edison Co., Brooklyn, N. Y.
Fellows, B. D., Detroit Edison Co., Detroit, Mich.
Fennelly, A. F., New York Edison Co., New York, N. Y.
Fisher, B. A., South Dakota State College, Brookings, S. Dakota
Flint, G. S., Edison Electric Illuminating Co., Boston, Mass.
Fricke, C., New York Edison Co., New York, N. Y.
Frost, A. E., Western Union Telegraph Co., New York, N. Y.
Fullerton, W. O., Bell Telephone Laboratories, Inc., New York, N. Y.
Fulton, A., General Electric Co., San Francisco, Calif.
Gates, C. W., Western Electric Co., Kearny, N. J.
Gilman, P. B., 77 Kirkstall Road, Newtonville, Mass.
Gladis, J., New England Power Co., Readsboro, Vt.
Godin, W. L. J. F., (Member), General Electric Co., Pittsfield, Mass.
Gorton, W. V., Westinghouse Elec. & Mfg. Co., Toledo, Ohio
Gridley, S. D., The Okonite Co., New York, N. Y.
(Applicant for re-election.)
Grosdoff, I. E., 147-17 11th St., Whitestone, N. Y.
Hansen, H., Riley Stoker Corp., Worcester, Mass.
Harris, J., (Member), Duncan Electric Mfg. Co., Lafayette, Ind.
Haughn, S. A., Willard Storage Battery Co., Cleveland, Ohio
Hemberger, E. F., Jr., Sea Gate Radio Research Labs., Sea Gate, N. Y.
Hill, J. B., Brooklyn Edison Co., Brooklyn, N. Y.
Hillenbrand, W. H., New York Telephone Co., New York, N. Y.
Horsfall, R. E., C. H. Tenney & Co., Boston, Mass.
Howe, F. R., Los Angeles Bureau of Power & Light, Saugua, Calif.
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Ziegler, A. W., Bell Telephone Laboratories, Inc., New York, N. Y.
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Iowa, University of, Iowa City, Iowa	Theo. VanLaw	E. J. Hartman	A. H. Ford
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Lewis Institute, Chicago, Ill	James S. Howe	O. D. Westerberg	F. A. Rogers
Louisiana State University, Baton Rouge, La	K. J. Ozment	E. P. Athens	M. B. Voorhies
Maine, University of, Orono, Me	P. E. Watson	R. F. Scott	W. E. Barrows, Jr.
Marquette University, Milwaukee, Wis	R. M. Franey	E. T. Baldwin	J. F .H. Douglas
Massachusetts Institute of Technology, Cambridge, Mass	Constantine Bary	E. A. Michelman	W. H. Timbie
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Minnesota, University of, Minneapolis, Minn	C H. Burmeister	J H. DuBois	H. Kuhlmann
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Missouri, University of, Columbia, Mo	V. L. Tiller	J. L. Egbert	M. P. Weinbach
Missouri School of Mines and Metallurgy, Rolla, Mo	W. J. Maulder	R. P. Baumgartner	I. H. Lovett
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Purdue University, Lafayette, Ind	A. Howard	T. B. Holliday	A. N. Topping
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Worcester Polytechnic Institute, Worcester, Mass	D A. Calder	C. H. Kauke	H. A. Maxfield
Wyoming, University of, Laramie, Wyo	John Hicks	Edward Joslin	G. H. Sechrist
Yale University, New Haven, Conn	W. W. Parker	J. W. Hinkley	Charles F. Scott
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NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Safety Switches.—Catalog and Price Lists. Describes Wadsworth meter service and industrial type safety switches. The Wadsworth Electric Mfg. Company, Covington, Ky.

Ball Bearings.—Bulletin, 20 pp. Describes the application of New Departure ball bearings in electric motors, and the advantages of their use. New Departure Mfg. Company, Bristol, Conn.

Oil Circuit Breakers.—Circular 1771, 12 pp. Describes the application, construction, operation and other distinctive features of types B-16, B-20 and B-26. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

Signal Equipment.—Bulletin 60-29A, 60 pp. Describes annunciators, bells, buzzers and signal equipment. A special section is devoted to central station annunciators. The bulletin contains numerous illustrations and is thumb-indexed. Chas. Cory & Son, Inc., 183 Varick Street, New York.

Air Filters.—Bulletin includes detail sheets of Midwest air filters, diagramatic installation methods and specifications. Another new bulletin, 4 pp., on air filters for compressors and engines is also available. Midwest Air Filters Company, Bradford, Pa.

Reactors.—Bulletin, 32 pp., "Manual of Reactor Protection." Describes Metropolitan current limiting reactors, principles of construction, outlines the tests to which they are subjected, and contains a list of present users. Metropolitan Device Corporation, 1250 Atlantic Avenue, Brooklyn, N. Y.

NOTES OF THE INDUSTRY

Edward Carpenter Wood, President of the Mica Insulator Company, died on February 17 in New York. A pioneer in the mica insulation industry, Mr. Wood played an important part in the development of Micanite, which was first put on the market by the Mica Insulator Company in 1893. Mr. Wood was identified with this company since its inception thirty-four years ago.

Hubbard & Company Holds Sales Conference.—During the week of January 31 the Electric Materials Department of Hubbard & Company held their third annual sales conference in Pittsburgh. The meeting was attended by all of the company's salesmen, district managers and three plant managers. The sales and advertising program for 1927 was discussed, and a complete territorial analysis was given by each salesman. Selling talks by sales managers of several large manufacturing concerns were also featured.

New Hazard Parkway Cable.—The Hazard Manufacturing Company, Wilkes-Barre, Pa., has placed on the market a parkway cable of somewhat lighter weight than customary conductors of this type. The new product is called "Loxsteel" cable, is armored with a single shaped steel strip, wrapped on the cable spirally and so formed as to interlock the convolutions, giving a protective steel sheath without any openings. Tests show the strength of the Loxsteel covering compares very favorably with that of the regular double flat steel covering. The lighter weight of the new cable effects a saving in freight charges and makes it somewhat easier to handle. Hazard Manufacturing Company, Wilkes-Barre, Pa.

Large Precipitator for Trenton Channel.—The first and only large installation of equipment for the electric precipitation of ash in a powdered fuel boiler plant is being installed at the Trenton Channel power plant of the Detroit Edison Company. The installation, having what will probably be the highest power rating of any single electric precipitation plant ever built, is being made under the supervision of the Research Corporation of New York City, and involves the use of the Cottrell process. The smoke given off from the Trenton Channel powdered fuel boiler plant carries with it a large amount of fine ash which, if it were not removed in some way, would result in the distribution from the stacks of many tons of ash over the surrounding countryside. By means of the new precipitator this will be practically eliminated.

The James R. Kearney Corporation Adds Sales Representatives.—The James R. Kearney Corporation, St. Louis, manufacturers of overhead and underground utility equipment, has made the following additions to its sales organization:

Oscar H. Davidson Equipment Company of 1633 Fremont Avenue, Denver, who will be representatives in the Denver territory. L. Brandenburger of 149-151 West 2nd South, Salt Lake City, representative in the Utah and Arizona territory. Theodore B. Dally, Room 303-E, 30 Church Street, New York City, who will be district representative in the New York and New Jersey territory. E. C. Dwelle, Room 1401 Allen Bldg., Dallas, district representative in Texas and Louisiana. H. C. Fiske, Asst. Engineer of this corporation, transferred to district representative in the Southeast territory, with headquarters in Atlanta. George A. Ackerman, 658 Victor Road, Erie, Pa., district representative in the Pittsburgh territory, covering Pennsylvania, Ohio, and part of New York.

Recent Westinghouse Orders.—A contract amounting to approximately $600,000 has been awarded to the Westinghouse Electric and Manufacturing Company by the Alabama Power Company for the complete generating equipment and entire quick response excitation system for installation in a new hydro electric station on the Coosa River. Included in this contract are four 29000 kv-a. 12,000 volt, 100 r. p. m., vertical waterwheel generators each machine complete with a 570 kv-a. 575 volt direct connected auxiliary generator mounted directly above the thrust bearing of the main alternator. Eight special exciter rheostatic generator voltage regulators are also included in the order. The United Electric Light & Power Company, and the New York Edison Company, have ordered four hundred automatic network protectors, 500 and 800 ampere non-submersible type. Another recent order is from the Commonwealth Edison Company, Chicago, for six 15,000 square foot, vertical type condensers and auxiliaries, which are to be installed at the Crawford Avenue Station.

R. C. Lanphier new President of Sangamo Electric Co.—Robert C. Lanphier has been elected president of the Sangamo Electric Company, Springfield, Illinois, to succeed the late Jacob Bunn, who had been president of the company since its foundation in 1899. Mr. Lanphier has been vice-president and general manager for the past ten years. He is also president of the Sangamo Electric Company of Canada, Limited, and director of the British Sangamo Company, Limited. Mr. Lanphier started with Mr. Bunn immediately after his graduation from the Sheffield Scientific School of Yale in 1897, to undertake the development of an electric meter. After a year of experimental work Mr. Bunn and Mr. Lanphier organized the Sangamo Electric Company. The new president is a Fellow of the American Institute of Electrical Engineers, and a director of the Society of Electrical Development.

Otis White, general superintendent, was elected vice-president in charge of manufacturing. Fred C. Holtz, chief engineer of the company and inventor of the Sangamo electric clock, which took the Grand Prix at the Sesqui-Centennial, was elected vice-president in charge of engineering.

College Graduates in General Electric Co.—More than 4100 college graduates are included in the ranks of the General Electric Company, a recent survey has shown. They are from 164 universities and colleges in this country, and from similar institutions in 34 foreign countries. The figures are exclusive of those in the lamp divisions of the company, and include only those who received college degrees.